



## 1. General description

The ISP1122 is a stand-alone Universal Serial Bus (USB) hub device which complies with *USB Specification Rev. 1.1*. It integrates a Serial Interface Engine (SIE), hub repeater, hub controller, USB data transceivers and a 3.3 V voltage regulator. It has a configurable number of downstream ports, ranging from 2 to 5.

The ISP1122 can be bus-powered, self-powered or hybrid-powered. When it is hybrid-powered the hub functions are powered by the upstream power supply ( $V_{BUS}$ ), but the downstream ports are powered by an external 5 Volt supply. The low power consumption in 'suspend' mode allows easy design of equipment that is compliant with the ACPI™, OnNow™ and USB power management requirements.

The ISP1122 has built-in overcurrent sense inputs, supporting individual and global overcurrent protection for downstream ports. All ports (including the hub) have GoodLink™ indicator outputs for easy visual monitoring of USB traffic. The ISP1122 has a serial I<sup>2</sup>C-bus interface for external EEPROM access and a reduced frequency (6 MHz) crystal oscillator. These features allow significant cost savings in system design and easy implementation of advanced USB functionality into PC peripherals.

## 2. Features

- High performance USB hub device with integrated hub repeater, hub controller, Serial Interface Engine (SIE), data transceivers and 3.3 V voltage regulator
- Complies with *Universal Serial Bus Specification Rev. 1.1* and ACPI, OnNow and USB power management requirements
- Configurable from 2 to 5 downstream ports with automatic speed detection
- Internal power-on reset and low voltage reset circuit
- Supports bus-powered, hybrid-powered and self-powered application
- Individual or ganged power switching for downstream ports
- Individual or global port overcurrent protection with built-in sense circuits
- 6 MHz crystal oscillator with on-chip PLL for low EMI
- Visual USB traffic monitoring (GoodLink™) for hub and downstream ports
- I<sup>2</sup>C-bus interface to read vendor ID, product ID and configuration bits from external EEPROM
- Operation over the extended USB bus voltage range (4.0 to 5.5 V)
- Operating temperature range –40 to +85 °C
- 8 kV in-circuit ESD protection for lower cost of external components

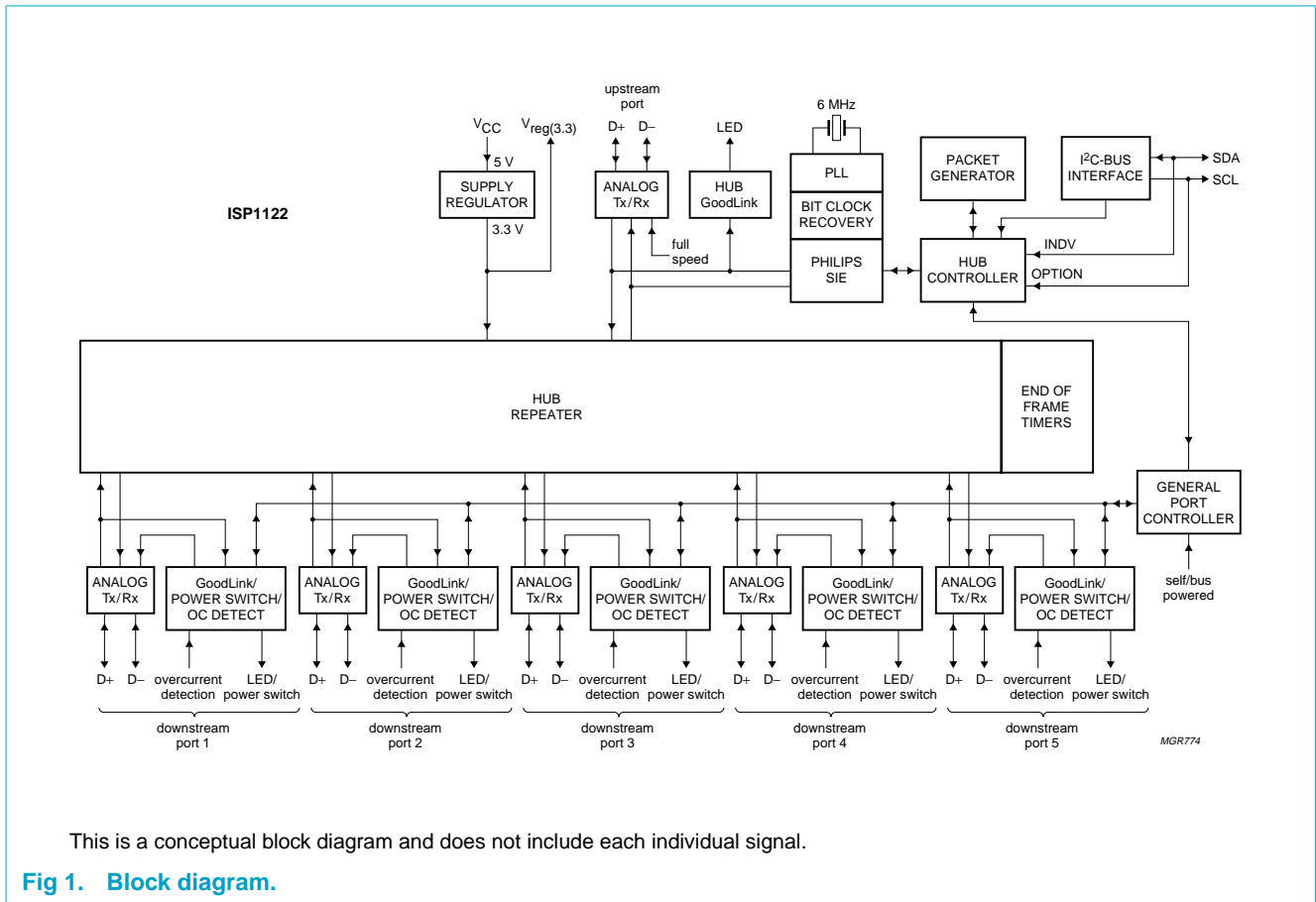
- Full-scan design with high test coverage
- Available in 32-pin SDIP, SO and LQFP packages.

### 3. Ordering information

Table 1: Ordering information

| Type number | Package |  | Version  |
|-------------|---------|--|----------|
|             | Name    | Description  |          |
| ISP1122D    | SO32    | plastic small outline package; 32 leads; body width 7.5 mm           | SOT287-1 |
| ISP1122NB   | SDIP32  | plastic shrink dual in-line package; 32 leads (400 mil)              | SOT232-1 |
| ISP1122BD   | LQFP32  | plastic low profile quad flat package; 32 leads; body 7 x 7 x 1.4 mm | SOT358-1 |

### 4. Block diagram



## 5. Pinning information

### 5.1 ISP1122D (SO32) and ISP1122NB (SDIP32)

#### 5.1.1 Pinning

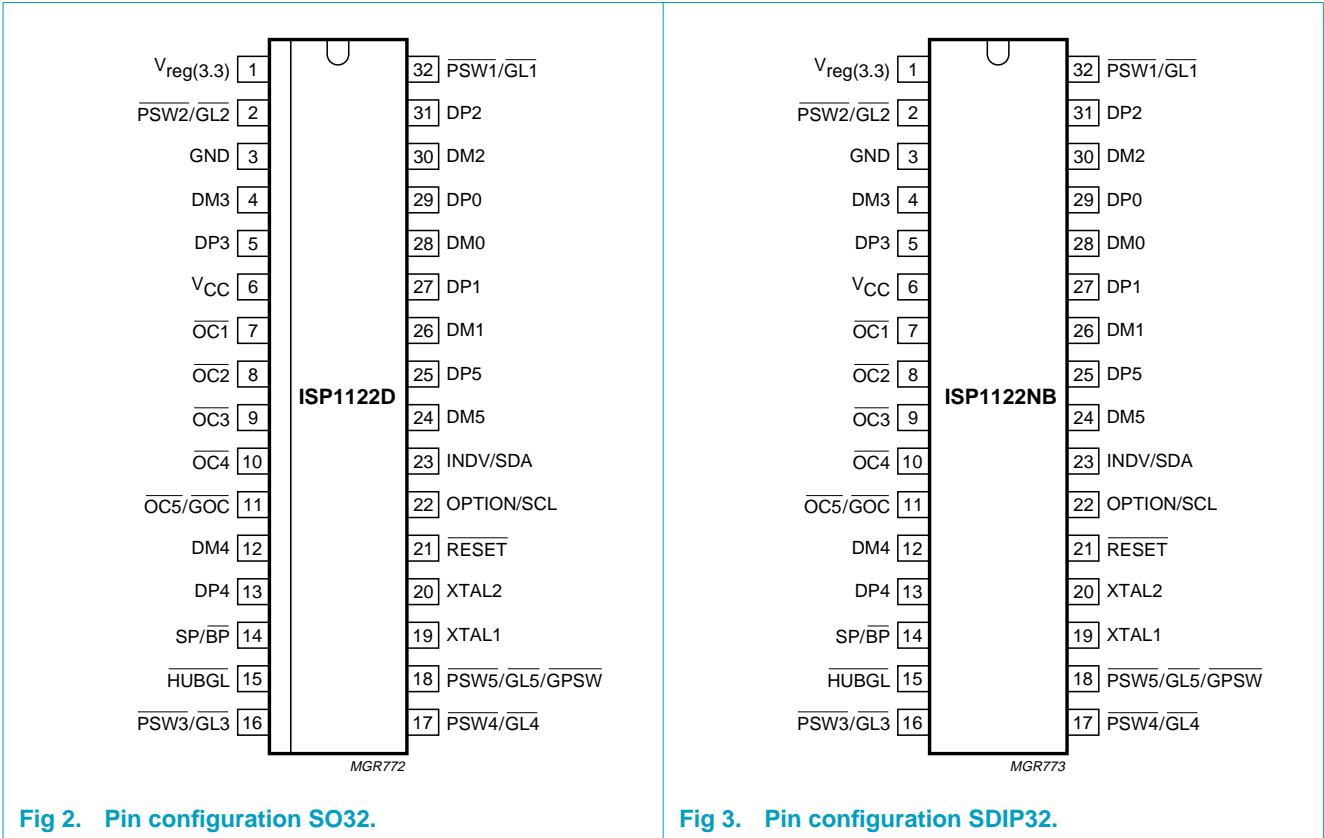


Fig 2. Pin configuration SO32.

Fig 3. Pin configuration SDIP32.

#### 5.1.2 Pin description

Table 2: Pin description for SO32 and SDIP32

| Symbol <sup>[1]</sup>                | Pin | Type | Description  |
|--------------------------------------|-----|------|--|
| V <sub>reg(3.3)</sub> <sup>[2]</sup> | 1   | -    | regulated supply voltage (3.3 V ± 10%) from internal regulator; used to connect pull-up resistor on DP0 line   |
| PSW2/GL2 <sup>[3]</sup>              | 2   | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 2 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 2 (open-drain, 6 mA); to connect an LED use a 330 Ω series resistor |
| GND                                  | 3   | -    | ground supply  |
| DM3                                  | 4   | AI/O | downstream port 3 D- connection (analog) <sup>[4]</sup>  |
| DP3                                  | 5   | AI/O | downstream port 3 D+ connection (analog) <sup>[4]</sup>  |
| V <sub>CC</sub>                      | 6   | -    | supply voltage; connect to USB supply V <sub>BUS</sub> (bus-powered or hybrid-powered) or to local supply V <sub>DD</sub> (self-powered)   |
| OC1                                  | 7   | AI/I | overcurrent sense input for downstream port 1 (analog) <sup>[5]</sup>  |

Table 2: Pin description for SO32 and SDIP32...continued

| Symbol <sup>[1]</sup>   | Pin | Type | Description   |
|---|-----|------|---|
| $\overline{OC2}$  | 8   | AI/I | overcurrent sense input for downstream port 2 (analog <sup>[5]</sup> )  |
| $\overline{OC3}$  | 9   | AI/I | overcurrent sense input for downstream port 3 (analog <sup>[5]</sup> )  |
| $\overline{OC4}$  | 10  | AI/I | overcurrent sense input for downstream port 4 (analog <sup>[5]</sup> )  |
| $\overline{OC5}/\overline{GOC}$ <sup>[3]</sup>                  | 11  | AI/I | <b>modes 5, 7:</b> overcurrent sense input for downstream port 5 (analog <sup>[5]</sup> )<br><b>modes 0, 1, 3:</b> global overcurrent sense input (analog <sup>[5]</sup> )  |
| DM4   | 12  | AI/O | downstream port 4 D– connection (analog) <sup>[4]</sup>   |
| DP4   | 13  | AI/O | downstream port 4 D+ connection (analog) <sup>[4]</sup>   |
| SP/ $\overline{BP}$   | 14  | I    | selects power mode:<br><b>self-powered:</b> connect to $V_{DD}$ (local power supply); also use this mode for hybrid-powered operation<br><b>bus-powered:</b> connect to GND; disable downstream port 5 to meet supply current requirements <sup>[4]</sup>   |
| $\overline{HUBGL}$  | 15  | O    | hub GoodLink LED indicator output (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor; if unused connect to $V_{CC}$ via a 10 k $\Omega$ resistor  |
| $\overline{PSW3}/\overline{GL3}$ <sup>[3]</sup>                 | 16  | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 3 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 3 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor   |
| $\overline{PSW4}/\overline{GL4}$ <sup>[3]</sup>                 | 17  | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 4 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 4 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor   |
| $\overline{PSW5}/\overline{GL5}/\overline{GPSW}$ <sup>[3]</sup> | 18  | O    | <b>mode 5:</b> power switch control output for downstream port 5 (open-drain, 6 mA)<br><b>modes 3, 7:</b> GoodLink LED indicator output for downstream port 5 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor<br><b>modes 0 to 2:</b> gang mode power switch control output (open-drain, 6 mA) |
| XTAL1   | 19  | I    | crystal oscillator input (6 MHz)  |
| XTAL2   | 20  | O    | crystal oscillator output (6 MHz)   |
| $\overline{RESET}$ <sup>[2]</sup>                               | 21  | I    | reset input (Schmitt trigger); a LOW level produces an asynchronous reset; connect to $V_{CC}$ for power-on reset (internal POR circuit)  |
| OPTION/SCL  | 22  | I/O  | mode selection input; also functions as I <sup>2</sup> C-bus clock output (open-drain, 6 mA)  |
| INDV/SDA  | 23  | I/O  | selects individual (HIGH) or global (LOW) power switching and overcurrent detection; also functions as bidirectional I <sup>2</sup> C-bus data line (open-drain, 6 mA)  |
| DM5   | 24  | AI/O | downstream port 5 D– connection (analog) <sup>[4]</sup>   |
| DP5   | 25  | AI/O | downstream port 5 D+ connection (analog) <sup>[4]</sup>   |
| DM1   | 26  | AI/O | downstream port 1 D– connection (analog) <sup>[6]</sup>   |

Table 2: Pin description for SO32 and SDIP32...continued

| Symbol <sup>[1]</sup>                        | Pin | Type | Description   |
|--|-----|------|---|
| DP1  | 27  | AI/O | downstream port 1 D+ connection (analog) <sup>[6]</sup>   |
| DM0  | 28  | AI/O | upstream port D– connection (analog)  |
| DP0  | 29  | AI/O | upstream port D+ connection (analog)  |
| DM2  | 30  | AI/O | downstream port 2 D– connection (analog) <sup>[6]</sup>   |
| DP2  | 31  | AI/O | downstream port 2 D+ connection (analog) <sup>[6]</sup>   |
| PSW1/ $\overline{\text{GL1}}$ <sup>[3]</sup> | 32  | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 1 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 1 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor |

- [1] Symbol names with an overscore (e.g.  $\overline{\text{NAME}}$ ) indicate active LOW signals.
- [2] The voltage at pin  $V_{\text{reg}(3,3)}$  is gated by the  $\overline{\text{RESET}}$  pin. This allows fully self-powered operation by connecting  $\overline{\text{RESET}}$  to  $V_{\text{BUS}}$  (+5 V USB supply). If  $V_{\text{BUS}}$  is lost upstream port D+ will not be driven.
- [3] See Table 4 “Mode selection”.
- [4] To disable a downstream port connect both D+ and D– to  $V_{\text{CC}}$  via a 1 M $\Omega$  resistor; unused ports must be disabled in reverse order starting from port 5.
- [5] Analog detection circuit can be switched off using an external EEPROM, see Table 23; in this case, the pin functions as a logic input (TTL level).
- [6] Downstream ports 1 and 2 cannot be disabled.

## 5.2 ISP1122BD (LQFP32)

### 5.2.1 Pinning

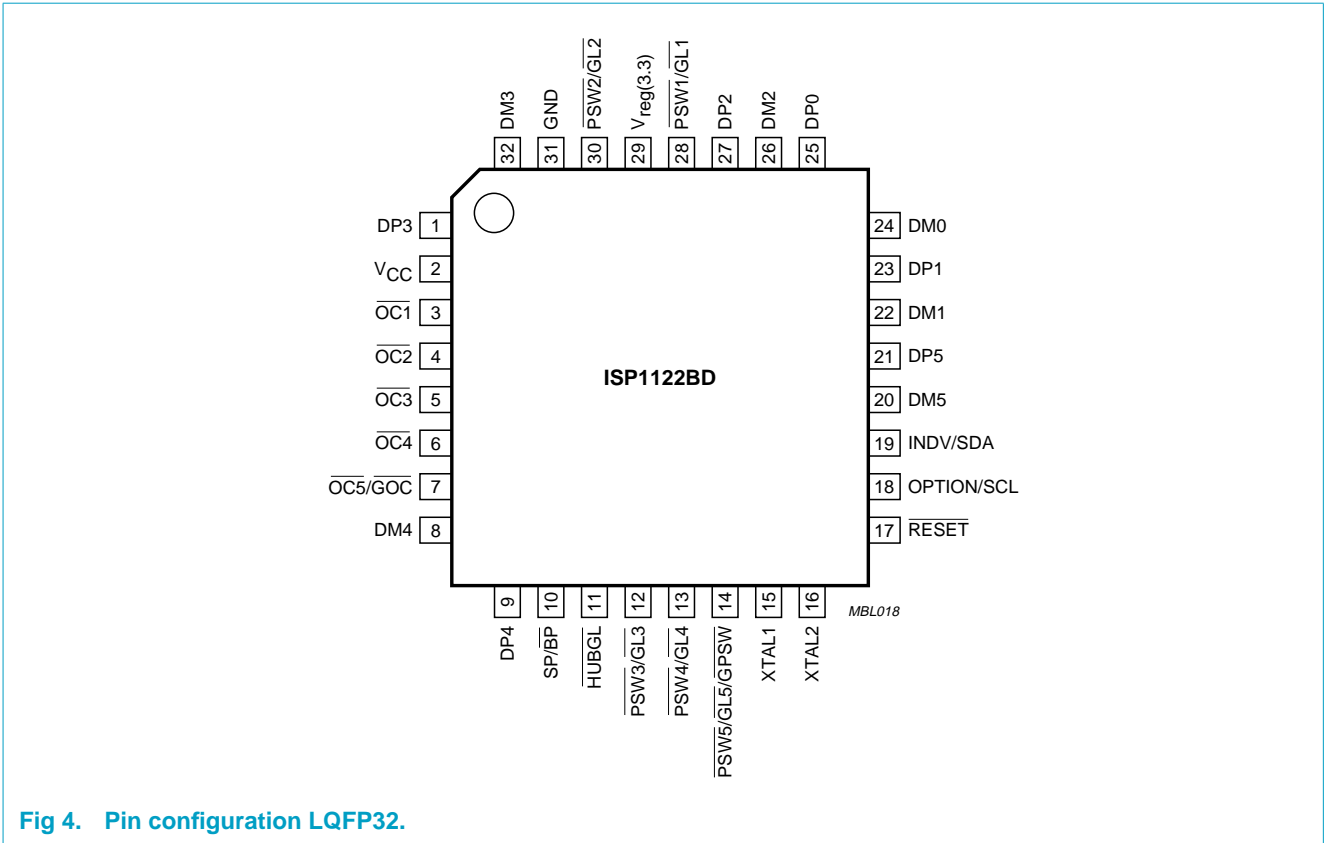


Fig 4. Pin configuration LQFP32.

### 5.2.2 Pin description

Table 3: Pin description for LQFP32

| Symbol <sup>[1]</sup>         | Pin | Type  | Description  |
|-------------------------------|-----|-------|--|
| $V_{reg(3.3)}$ <sup>[2]</sup> | 29  | -     | regulated supply voltage (3.3 V ± 10%) from internal regulator; used to connect pull-up resistor on DP0 line   |
| PSW2/GL2 <sup>[3]</sup>       | 30  | O     | <b>modes 4 to 6:</b> power switch control output for downstream port 2 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 2 (open-drain, 6 mA); to connect an LED use a 330 Ω series resistor |
| GND                           | 31  | -     | ground supply  |
| DM3                           | 32  | A/I/O | downstream port 3 D- connection (analog) <sup>[4]</sup>  |
| DP3                           | 1   | A/I/O | downstream port 3 D+ connection (analog) <sup>[4]</sup>  |
| $V_{CC}$                      | 2   | -     | supply voltage; connect to USB supply $V_{BUS}$ (bus-powered or hybrid-powered) or to local supply $V_{DD}$ (self-powered)   |
| $\overline{OC1}$              | 3   | A/I   | overcurrent sense input for downstream port 1 (analog) <sup>[5]</sup>  |
| $\overline{OC2}$              | 4   | A/I   | overcurrent sense input for downstream port 2 (analog) <sup>[5]</sup>  |
| $\overline{OC3}$              | 5   | A/I   | overcurrent sense input for downstream port 3 (analog) <sup>[5]</sup>  |
| $\overline{OC4}$              | 6   | A/I   | overcurrent sense input for downstream port 4 (analog) <sup>[5]</sup>  |

Table 3: Pin description for LQFP32...continued

| Symbol <sup>[1]</sup>            | Pin | Type | Description   |
|----------------------------------|-----|------|---|
| OC5/GOC <sup>[3]</sup>           | 7   | AI/I | <b>modes 5, 7:</b> overcurrent sense input for downstream port 5 (analog <sup>[5]</sup> )<br><b>modes 0, 1, 3:</b> global overcurrent sense input (analog <sup>[5]</sup> )  |
| DM4                              | 8   | AI/O | downstream port 4 D– connection (analog) <sup>[4]</sup>   |
| DP4                              | 9   | AI/O | downstream port 4 D+ connection (analog) <sup>[4]</sup>   |
| SP/BP                            | 10  | I    | selects power mode:<br><b>self-powered:</b> connect to $V_{DD}$ (local power supply); also use this mode for hybrid-powered operation<br><b>bus-powered:</b> connect to GND; disable downstream port 5 to meet supply current requirements <sup>[4]</sup>   |
| HUBGL                            | 11  | O    | hub GoodLink LED indicator output (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor; if unused connect to $V_{CC}$ via a 10 k $\Omega$ resistor  |
| PSW3/GL3 <sup>[3]</sup>          | 12  | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 3 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 3 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor   |
| PSW4/GL4 <sup>[3]</sup>          | 13  | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 4 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 4 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor   |
| PSW5/GL5/<br>GPSW <sup>[3]</sup> | 14  | O    | <b>mode 5:</b> power switch control output for downstream port 5 (open-drain, 6 mA)<br><b>modes 3, 7:</b> GoodLink LED indicator output for downstream port 5 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor<br><b>modes 0 to 2:</b> gang mode power switch control output (open-drain, 6 mA) |
| XTAL1                            | 15  | I    | crystal oscillator input (6 MHz)  |
| XTAL2                            | 16  | O    | crystal oscillator output (6 MHz)   |
| RESET <sup>[2]</sup>             | 17  | I    | reset input (Schmitt trigger); a LOW level produces an asynchronous reset; connect to $V_{CC}$ for power-on reset (internal POR circuit)  |
| OPTION/SCL                       | 18  | I/O  | mode selection input; also functions as I <sup>2</sup> C-bus clock output (open-drain, 6 mA)  |
| INDV/SDA                         | 19  | I/O  | selects individual (HIGH) or global (LOW) power switching and overcurrent detection; also functions as bidirectional I <sup>2</sup> C-bus data line (open-drain, 6 mA)  |
| DM5                              | 20  | AI/O | downstream port 5 D– connection (analog) <sup>[4]</sup>   |
| DP5                              | 21  | AI/O | downstream port 5 D+ connection (analog) <sup>[4]</sup>   |
| DM1                              | 22  | AI/O | downstream port 1 D– connection (analog) <sup>[6]</sup>   |
| DP1                              | 23  | AI/O | downstream port 1 D+ connection (analog) <sup>[6]</sup>   |
| DM0                              | 24  | AI/O | upstream port D– connection (analog)  |
| DP0                              | 25  | AI/O | upstream port D+ connection (analog)  |

Table 3: Pin description for LQFP32...continued

| Symbol <sup>[1]</sup>   | Pin | Type | Description   |
|-------------------------|-----|------|---|
| DM2                     | 26  | AI/O | downstream port 2 D- connection (analog) <sup>[6]</sup>   |
| DP2                     | 27  | AI/O | downstream port 2 D+ connection (analog) <sup>[6]</sup>   |
| PSW1/GL1 <sup>[3]</sup> | 28  | O    | <b>modes 4 to 6:</b> power switch control output for downstream port 1 (open-drain, 6 mA)<br><b>modes 0 to 3, 7:</b> GoodLink LED indicator output for downstream port 1 (open-drain, 6 mA); to connect an LED use a 330 $\Omega$ series resistor |

- [1] Symbol names with an overscore (e.g.  $\overline{NAME}$ ) indicate active LOW signals.
- [2] The voltage at pin  $V_{reg(3.3)}$  is gated by the  $\overline{RESET}$  pin. This allows fully self-powered operation by connecting  $\overline{RESET}$  to  $V_{BUS}$  (+5 V USB supply). If  $V_{BUS}$  is lost upstream port D+ will not be driven.
- [3] See Table 4 "Mode selection".
- [4] To disable a downstream port connect both D+ and D- to  $V_{CC}$  via a 1 M $\Omega$  resistor; unused ports must be disabled in reverse order starting from port 5.
- [5] Analog detection circuit can be switched off using an external EEPROM, see Table 23; in this case, the pin functions as a logic input (TTL level).
- [6] Downstream ports 1 and 2 cannot be disabled.

## 6. Functional description

The ISP1122 is a stand-alone USB hub with up to 5 downstream ports. The number of ports can be configured between 2 and 5. The downstream ports can be used to connect low-speed or full-speed USB peripherals. All standard USB requests from the host are handled by the hardware without the need for firmware intervention. The block diagram is shown in Figure 1.

The ISP1122 requires only a single supply voltage. An internal 3.3 V regulator provides the supply voltage for the analog USB data transceivers.

The ISP1122 supports both bus-powered and self-powered hub operation. When using bus-powered operation a downstream port cannot supply more than 100 mA to a peripheral. In case of self-powered operation an external supply is used to power the downstream ports, allowing a current consumption of max. 500 mA per port.

A basic I<sup>2</sup>C-bus interface is provided for reading vendor ID, product ID and configuration bits from an external EEPROM upon a reset.

### 6.1 Analog transceivers

The integrated transceiver interfaces directly to the USB cables through external termination resistors. They are capable of transmitting and receiving serial data at both 'full-speed' (12 Mbit/s) and 'low-speed' (1.5 Mbit/s) data rates. The slew rates are adjusted according to the speed of the device connected and lie within the range mentioned in the *USB Specification Rev. 1.1*.



## 6.2 Philips Serial Interface Engine (SIE)

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 (de-)stuffing, CRC checking/generation, Packet Identifier (PID) verification/generation, address recognition, handshake evaluation/generation.

## 6.3 Hub repeater

The hub repeater is responsible for managing connectivity on a 'per packet' basis. It implements 'packet signalling' and 'resume' connectivity. Low-speed devices can be connected to downstream ports. If a low-speed device is detected the repeater will not propagate upstream packets to the corresponding port, unless they are preceded by a PREAMBLE PID.

## 6.4 End-of-frame timers

This block contains the specified EOF1 and EOF2 timers which are used to detect 'loss-of-activity' and 'babble' error conditions in the hub repeater. The timers also maintain the low-speed keep-alive strobe which is sent at the beginning of a frame.

## 6.5 General and individual port controller

The general and individual port controllers together provide status and control of individual downstream ports. Any port status change will be reported to the host via the hub status change (interrupt) endpoint.

## 6.6 GoodLink

Indication of a good USB connection is provided through GoodLink technology. An LED can be directly connected via an external 330  $\Omega$  resistor.

During enumeration the LED blinks momentarily. After successful configuration of the ISP1122, the LED is permanently on. The LED blinks off for 100 ms upon each successful packet transfer (with ACK). The hub GoodLink indicator blinks when the hub receives a packet addressed to it. Downstream GoodLink indicators blink upon an acknowledgment from the associated port. In 'suspend' mode the LED is off.

This feature provides a user-friendly indication of the status of the hub, the connected downstream devices and the USB traffic. It is a useful diagnostics tool to isolate faulty USB equipment and helps to reduce field support and hotline costs.

## 6.7 Bit clock recovery

The bit clock recovery circuit recovers the clock from the incoming USB data stream using a 4 $\times$  oversampling principle. It is able to track jitter and frequency drift as specified by the *USB Specification Rev. 1.1*.

## 6.8 Voltage regulator

A 5 to 3.3 V DC-DC regulator is integrated on-chip to supply the analog transceiver and internal logic. This can also be used to supply the terminal 1.5 k $\Omega$  pull-up resistor on the D+ line of the upstream connection.

## 6.9 PLL clock multiplier

A 6 to 48 MHz clock multiplier Phase-Locked Loop (PLL) is integrated on-chip. This allows for the use of low-cost 6 MHz crystals. The low crystal frequency also minimizes Electro-Magnetic Interference (EMI). The PLL requires no external components.

## 6.10 Overcurrent detection

An overcurrent detection circuit for downstream ports has been integrated on-chip. It is self-reporting, resets automatically, has a low trip time and requires no external components. Both individual and global overcurrent detection are supported.

## 6.11 I<sup>2</sup>C-bus interface

A basic serial I<sup>2</sup>C-bus interface (single master, 100 kHz) is provided to read VID, PID and configuration bits from an external I<sup>2</sup>C-bus EEPROM (e.g. Philips PCF8582 or equivalent). At reset the ISP1122 reads 6 bytes of data from the external memory.

The I<sup>2</sup>C-bus interface timing complies with the standard mode of operation as described in *The I<sup>2</sup>C-bus and how to use it*, order number 9398 393 40011.

## 7. Modes of operation

The ISP1122 has several modes of operation, each corresponding with a different pin configuration. Modes are selected by means of pins INDV, OPTION and SP/BP, as shown in [Table 4](#).

**Table 4: Mode selection**

| Mode | INDV<br><sup>[1]</sup> | OPTION | SP/BP<br><sup>[2]</sup> | PSWn/GLn<br>(n = 1 to 4) | PSW5/GL5/GPSW           | OCn<br>(n = 1 to 4)     | OC5/GOC                 |
|------|------------------------|--------|-------------------------|--------------------------|-------------------------|-------------------------|-------------------------|
| 0    | 0                      | 0      | 0                       | GoodLink                 | ganged power            | inactive                | global overcurrent      |
| 1    | 0                      | 0      | 1                       | GoodLink                 | ganged power            | inactive                | global overcurrent      |
| 2    | 0                      | 1      | 0                       | GoodLink                 | ganged power            | inactive <sup>[3]</sup> | inactive <sup>[3]</sup> |
| 3    | 0                      | 1      | 1                       | GoodLink <sup>[4]</sup>  | GoodLink <sup>[4]</sup> | inactive                | global overcurrent      |
| 4    | 1                      | 0      | 0                       | individual power         | inactive                | individual overcurrent  | inactive                |
| 5    | 1                      | 0      | 1                       | individual power         | individual power        | individual overcurrent  | individual overcurrent  |
| 6    | 1                      | 1      | 0                       | individual power         | inactive                | inactive <sup>[3]</sup> | inactive <sup>[3]</sup> |
| 7    | 1                      | 1      | 1                       | GoodLink <sup>[4]</sup>  | GoodLink <sup>[4]</sup> | individual overcurrent  | individual overcurrent  |

[1] Port power switching: logic 0 = ganged, logic 1 = individual.

[2] Power mode: logic 0 = bus-powered, logic 1 = self-powered (or hybrid-powered).

[3] No overcurrent detection.

[4] No power switching.

## 8. Endpoint descriptions

Each USB device is logically composed of several independent endpoints. An endpoint acts as a terminus of a communication flow between the host and the device. At design time each endpoint is assigned a unique number (endpoint identifier, see [Table 5](#)). The combination of the device address (given by the host during enumeration), the endpoint number and the transfer direction allows each endpoint to be uniquely referenced.

The ISP1122 has two endpoints, endpoint 0 (control) and endpoint 1 (interrupt).

**Table 5: Hub endpoints**

| Function | Ports              | Endpoint identifier | Transfer type | Direction <sup>[1]</sup> | Max. packet size (bytes) |
|----------|--------------------|---------------------|---------------|--------------------------|--------------------------|
| Hub      | 0: upstream        | 0                   | control       | OUT                      | 64                       |
|          |                    |                     |               | IN                       | 64                       |
|          | 1 to 5: downstream | 1                   | interrupt     | IN                       | 1                        |

[1] IN: input for the USB host; OUT: output from the USB host.

### 8.1 Hub endpoint 0 (control)

All USB devices and functions must implement a default control endpoint (ID = 0). This endpoint is used by the host to configure the device and to perform generic USB status and control access.

The ISP1122 hub supports the following USB descriptor information through its control endpoint 0, which can handle transfers of 64 bytes maximum:

- Device descriptor
- Configuration descriptor
- Interface descriptor
- Endpoint descriptor
- Hub descriptor
- String descriptor.

### 8.2 Hub endpoint 1 (interrupt)

Endpoint 1 is used by the ISP1122 hub to provide status change information to the host. This endpoint can be accessed only after the hub has been configured by the host (by sending the Set Configuration command).

Endpoint 1 is an interrupt endpoint: the host polls it once every 255 ms by sending an IN token. If the hub has detected no change in the port status it returns a NAK (Not Acknowledge) response to this request, otherwise it sends the Status Change byte (see [Table 6](#)).

**Table 6: Status Change byte: bit allocation**

| Bit | Symbol    | Description  |
|-----|-----------|--|
| 0   | Hub SC    | a logic 1 indicates a status change on the hub's upstream port |
| 1   | Port 1 SC | a logic 1 indicates a status change on downstream port 1       |
| 2   | Port 2 SC | a logic 1 indicates a status change on downstream port 2       |
| 3   | Port 3 SC | a logic 1 indicates a status change on downstream port 3       |
| 4   | Port 4 SC | a logic 1 indicates a status change on downstream port 4       |
| 5   | Port 5 SC | a logic 1 indicates a status change on downstream port 5       |
| 6   | reserved  | not used   |
| 7   | reserved  | not used   |

## 9. Host requests

The ISP1122 handles all standard USB requests from the host via control endpoint 0. The control endpoint can handle a maximum of 64 bytes per transfer.

**Remark:** Please note that the USB data transmission order is Least Significant Bit (LSB) first. In the following tables multi-byte variables are displayed least significant byte first.

### 9.1 Standard requests

**Table 7** shows the supported standard USB requests. Some requests are explicitly unsupported. All other requests will be responded with a STALL packet.

**Table 7: Standard USB requests**

| Request name                    | bmRequestType<br>byte 0 [7:0]<br>(Bin) | bRequest<br>byte 1<br>(Hex) | wValue<br>byte 2, 3<br>(Hex) | wIndex<br>byte 4, 5<br>(Hex) | wLength<br>byte 6, 7<br>(Hex) | Data   |
|---------------------------------|--|-----------------------------|------------------------------|------------------------------|-------------------------------|--|
| <b>Address</b>                  |  |                             |                              |                              |                               |  |
| Set Address                     | X000 0000                              | 05                          | address <sup>[1]</sup>       | 00, 00                       | 00, 00                        | none   |
| <b>Configuration</b>            |  |                             |                              |                              |                               |  |
| Get Configuration               | 1000 0000                              | 08                          | 00, 00                       | 00, 00                       | 01, 00                        | configuration<br>value = 01H                               |
| Set Configuration (0)           | X000 0000                              | 09                          | 00, 00                       | 00, 00                       | 00, 00                        | none   |
| Set Configuration (1)           | X000 0000                              | 09                          | 01, 00                       | 00, 00                       | 00, 00                        | none   |
| <b>Descriptor</b>               |  |                             |                              |                              |                               |  |
| Get Configuration<br>Descriptor | 1000 0000                              | 06                          | 00, 02                       | 00, 00                       | length <sup>[2]</sup>         | configuration,<br>interface and<br>endpoint<br>descriptors |
| Get Device Descriptor           | 1000 0000                              | 06                          | 00, 01                       | 00, 00                       | length <sup>[2]</sup>         | device<br>descriptor                                       |
| Get String Descriptor (0)       | 1000 0000                              | 06                          | 03, 00                       | 00, 00                       | length <sup>[2]</sup>         | language ID<br>string                                      |
| Get String Descriptor (1)       | 1000 0000                              | 06                          | 03, 01                       | 00, 00                       | length <sup>[2]</sup>         | manufacturer<br>string                                     |
| Get String Descriptor (2)       | 1000 0000                              | 06                          | 03, 02                       | 00, 00                       | length <sup>[2]</sup>         | product string   |

Table 7: Standard USB requests...continued

| Request name                               | bmRequestType<br>byte 0 [7:0]<br>(Bin) | bRequest<br>byte 1<br>(Hex) | wValue<br>byte 2, 3<br>(Hex) | wIndex<br>byte 4, 5<br>(Hex) | wLength<br>byte 6, 7<br>(Hex) | Data                 |
|--|--|-----------------------------|------------------------------|------------------------------|-------------------------------|----------------------|
| <b>Feature</b>                             |  |                             |                              |                              |                               |                      |
| Clear Device Feature<br>(REMOTE_WAKEUP)    | X000 0000                              | 01                          | 01, 00                       | 00, 00                       | 00, 00                        | none                 |
| Clear Endpoint (1)<br>Feature (HALT/STALL) | X000 0010                              | 01                          | 00, 00                       | 81, 00                       | 00, 00                        | none                 |
| Set Device Feature<br>(REMOTE_WAKEUP)      | X000 0000                              | 03                          | 01, 00                       | 00, 00                       | 00, 00                        | none                 |
| Set Endpoint (1)<br>Feature (HALT/STALL)   | X000 0010                              | 03                          | 00, 00                       | 81, 00                       | 00, 00                        | none                 |
| <b>Status</b>                              |  |                             |                              |                              |                               |                      |
| Get Device Status                          | 1000 0000                              | 00                          | 00, 00                       | 00, 00                       | 02, 00                        | device status        |
| Get Interface Status                       | 1000 0001                              | 00                          | 00, 00                       | 00, 00                       | 02, 00                        | zero                 |
| Get Endpoint (0) Status                    | 1000 0010                              | 00                          | 00, 00                       | 00/80 <sup>[3]</sup> , 00    | 02, 00                        | endpoint 0<br>status |
| Get Endpoint (1) Status                    | 1000 0010                              | 00                          | 00, 00                       | 81, 00                       | 02, 00                        | endpoint 1<br>status |
| <b>Unsupported</b>                         |  |                             |                              |                              |                               |                      |
| Set Descriptor                             | 0000 0000                              | 07                          | XX, XX                       | XX, XX                       | XX, XX                        | descriptor;<br>STALL |
| Get Interface                              | 1000 0001                              | 0A                          | 00, 00                       | XX, XX                       | 01, 00                        | STALL                |
| Set Interface                              | X000 0001                              | 0B                          | XX, XX                       | XX, XX                       | 00, 00                        | STALL                |
| Synch Frame                                | 1000 0010                              | 0C                          | 00, 00                       | XX, XX                       | 02, 00                        | STALL                |

[1] Device address: 0 to 127.

[2] Returned value in bytes.

[3] MSB specifies endpoint direction: 0 = OUT, 1 = IN. The ISP1122 accepts either value.

## 9.2 Hub specific requests

In [Table 8](#) the supported hub specific requests are listed, as well as some unsupported requests. [Table 9](#) provides the feature selectors for setting or clearing port features.

Table 8: Hub specific requests

| Request name                              | bmRequestType<br>byte 0 [7:0]<br>(Bin) | bRequest<br>byte 1<br>(Hex) | wValue<br>byte 2, 3<br>(Hex) | wIndex<br>byte 4, 5<br>(Hex) | wLength<br>byte 6, 7<br>(Hex) | Data           |
|---|--|-----------------------------|------------------------------|------------------------------|-------------------------------|----------------|
| <b>Descriptor</b>                         |  |                             |                              |                              |                               |                |
| Get Hub Descriptor                        | 1010 0000                              | 06                          | 00, 00/29 <sup>[1]</sup>     | 00, 00                       | length <sup>[2]</sup> , 00    | hub descriptor |
| <b>Feature</b>                            |  |                             |                              |                              |                               |                |
| Clear Hub Feature<br>(C_LOCAL_POWER)      | X010 0000                              | 01                          | 00, 00                       | 00, 00                       | 00, 00                        | none           |
| Clear Port Feature<br>(feature selectors) | X010 0011                              | 01                          | feature <sup>[3]</sup> , 00  | port <sup>[4]</sup> , 00     | 00, 00                        | none           |
| Set Port Feature<br>(feature selectors)   | X010 0011                              | 03                          | feature <sup>[3]</sup> , 00  | port <sup>[4]</sup> , 00     | 00, 00                        | none           |

Table 8: Hub specific requests...continued

| Request name                       | bmRequestType byte 0 [7:0] (Bin) | bRequest byte 1 (Hex) | wValue byte 2, 3 (Hex) | wIndex byte 4, 5 (Hex)   | wLength byte 6, 7 (Hex) | Data                               |
|------------------------------------|----------------------------------|-----------------------|------------------------|--------------------------|-------------------------|------------------------------------|
| <b>Status</b>                      |                                  |                       |                        |                          |                         |                                    |
| Get Hub Status                     | 1010 0000                        | 00                    | 00, 00                 | 00, 00                   | 04, 00                  | hub status and status change field |
| Get Port Status                    | 1010 0011                        | 00                    | 00, 00                 | port <sup>[4]</sup> , 00 | 04, 00                  | port status                        |
| <b>Unsupported</b>                 |                                  |                       |                        |                          |                         |                                    |
| Get Bus Status                     | 1010 0011                        | 02                    | 00, 00                 | port <sup>[4]</sup> , 00 | 01, 00                  | STALL                              |
| Clear Hub Feature (C_OVER_CURRENT) | X010 0000                        | 01                    | 01, 00                 | 00, 00                   | 00, 00                  | STALL                              |
| Set Hub Descriptor                 | 0010 0000                        | 07                    | XX, XX                 | 00, 00                   | 3E, 00                  | STALL                              |
| Set Hub Feature (C_LOCAL_POWER)    | X010 0000                        | 03                    | 00, 00                 | 00, 00                   | 00, 00                  | STALL                              |
| Set Hub Feature (C_OVER_CURRENT)   | X010 0000                        | 03                    | 01, 00                 | 00, 00                   | 00, 00                  | STALL                              |

- [1] USB Specification Rev. 1.0 uses 00H, USB Specification Rev. 1.1 specifies 29H.
- [2] Returned value in bytes.
- [3] Feature selector value, see Table 9.
- [4] Downstream port identifier: 1 to N with N = number of enabled ports (2 to 5).

Table 9: Port feature selectors

| Feature selector name | Value (Hex) | Set feature               | Clear feature                      |
|-----------------------|-------------|---------------------------|------------------------------------|
| PORT_CONNECTION       | 00          | not used                  | not used                           |
| PORT_ENABLE           | 01          | not used                  | disables a port                    |
| PORT_SUSPEND          | 02          | suspends a port           | resumes a port                     |
| PORT_OVERCURRENT      | 03          | not used                  | not used                           |
| PORT_RESET            | 04          | resets and enables a port | not used                           |
| PORT_POWER            | 08          | powers on a port          | powers off a port                  |
| PORT_LOW_SPEED        | 09          | not used                  | not used                           |
| C_PORT_CONNECTION     | 10          | not used                  | clears port connection change bit  |
| C_PORT_ENABLE         | 11          | not used                  | clears port enable change bit      |
| C_PORT_SUSPEND        | 12          | not used                  | clears port suspend change bit     |
| C_PORT_OVERCURRENT    | 13          | not used                  | clears port overcurrent change bit |
| C_PORT_RESET          | 14          | not used                  | clears port reset change bit       |

### 9.3 Descriptors

The ISP1122 hub controller supports the following standard USB descriptors:

- Device
- Configuration
- Interface
- Endpoint
- Hub
- String.

**Table 10: Device descriptor**

*Values in square brackets are optional.*

| Offset (bytes) | Field name         | Size (bytes) | Value (Hex) | Comments  |
|----------------|--------------------|--------------|-------------|---|
| 0              | bLength            | 1            | 12          | descriptor length = 18 bytes  |
| 1              | bDescriptorType    | 1            | 01          | type = DEVICE   |
| 2              | bcdUSB             | 2            | 10, 01      | <i>USB Specification Rev. 1.1</i>   |
| 4              | bDeviceClass       | 1            | 09          | HUB_CLASSCODE   |
| 5              | bDeviceSubClass    | 1            | 00          | -   |
| 6              | bDeviceProtocol    | 1            | 00          | -   |
| 7              | bMaxPacketSize0    | 1            | 40          | packet size = 64 bytes  |
| 8              | idVendor           | 2            | CC, 04      | Philips Semiconductors vendor ID (04CC); can be customized using an external EEPROM (see <a href="#">Table 23</a> ) |
| 10             | idProduct          | 2            | 22, 11      | ISP1122 product ID; can be customized using an external EEPROM (see <a href="#">Table 23</a> )                      |
| 12             | bcdDevice          | 2            | 01, 01      | device release 1.1; silicon revision increments this value  |
| 14             | iManufacturer      | 1            | 00          | no manufacturer string (default)  |
|                |                    |              | [01]        | manufacturer string enabled (using an external EEPROM)  |
| 15             | iProduct           | 1            | 00          | no product string (default)   |
|                |                    |              | [02]        | product string enabled (using an external EEPROM)   |
| 16             | iSerialNumber      | 1            | 00          | no serial number string   |
| 17             | bNumConfigurations | 1            | 01          | one configuration   |

**Table 11: Configuration descriptor***Values in square brackets are optional.*

| Offset (bytes) | Field name              | Size (bytes) | Value (Hex) | Comments   |
|----------------|-------------------------|--------------|-------------|--|
| 0              | bLength                 | 1            | 09          | descriptor length = 9 bytes  |
| 1              | bDescriptorType         | 1            | 02          | type = CONFIGURATION   |
| 2              | wTotalLength            | 2            | 19, 00      | total length of configuration, interface and endpoint descriptors (25 bytes) |
| 4              | bNumInterfaces          | 1            | 01          | one interface  |
| 5              | bConfigurationValue     | 1            | 01          | configuration value = 1  |
| 6              | iConfiguration          | 1            | 00          | no configuration string  |
| 7              | bmAttributes            | 1            | E0          | self-powered with remote wake-up <sup>[1]</sup>                              |
|                |                         |              | A0          | bus-powered with remote wake-up <sup>[1]</sup>                               |
| 8              | MaxPower <sup>[2]</sup> | 1            | 32          | 100 mA (default)   |
|                |                         |              | [00]        | 0 mA (using an external EEPROM)  |
|                |                         |              | [FA]        | 500 mA (using an external EEPROM)  |

[1] Selected by input SP/BP.

[2] Value in units of 2 mA.

**Table 12: Interface descriptor**

| Offset (bytes) | Field name         | Size (bytes) | Value (Hex) | Comments                           |
|----------------|--------------------|--------------|-------------|------------------------------------|
| 0              | bLength            | 1            | 09          | descriptor length = 9 bytes        |
| 1              | bDescriptorType    | 1            | 04          | type = INTERFACE                   |
| 2              | bInterfaceNumber   | 1            | 00          | -                                  |
| 3              | bAlternateSetting  | 1            | 01          | no alternate setting               |
| 4              | bNumEndpoints      | 1            | 01          | status change (interrupt) endpoint |
| 5              | bInterfaceClass    | 1            | 09          | HUB_CLASSCODE                      |
| 6              | bInterfaceSubClass | 1            | 00          | -                                  |
| 7              | bInterfaceProtocol | 1            | 00          | no class-specific protocol         |
| 8              | bInterface         | 1            | 00          | no interface string                |

**Table 13: Endpoint descriptor**

| Offset (bytes) | Field name       | Size (bytes) | Value (Hex) | Comments                    |
|----------------|------------------|--------------|-------------|-----------------------------|
| 0              | bLength          | 1            | 07          | descriptor length = 7 bytes |
| 1              | bDescriptorType  | 1            | 05          | type = ENDPOINT             |
| 2              | bEndpointAddress | 1            | 81          | endpoint 1, direction: IN   |
| 3              | bmAttributes     | 1            | 03          | interrupt endpoint          |
| 4              | wMaxPacketSize   | 2            | 01, 00      | packet size = 1 byte        |
| 6              | bInterval        | 1            | FF          | polling interval (255 ms)   |



**Table 14: Hub descriptor**

Values in square brackets are optional.

| Offset (bytes) | Field name                    | Size (bytes) | Value (Hex) | Comments   |
|----------------|-------------------------------|--------------|-------------|--|
| 0              | bDescLength                   | 1            | 09          | descriptor length = 9 bytes  |
| 1              | bDescriptorType               | 1            | 29          | type = HUB   |
| 2              | bNbrPorts                     | 1            | 05 to 02    | number of enabled downstream ports; selectable by DP/DM strapping                                  |
| 3              | wHubCharacteristics           | 2            | 09, 00      | individual power switching <sup>[1]</sup> , overcurrent protection active (modes 0, 1, 3, 4, 5, 7) |
|                |                               |              | 11, 00      | individual power switching <sup>[1]</sup> , no overcurrent protection (modes 2, 6) <sup>[2]</sup>  |
| 5              | bPwrOn2PwrGood <sup>[3]</sup> | 1            | 32          | 100 ms (default; modes 0, 1, 2, 4, 5, 6)   |
|                |                               |              | 00          | 0 ms (default; modes 3, 7)   |
|                |                               |              | [FA]        | 500 ms (using an external EEPROM; modes 0, 1, 2, 4, 5, 6); see <a href="#">Table 23</a>            |
| 6              | bHubContrCurrent              | 1            | 64          | maximum hub controller current (100 mA)  |
| 7              | DeviceRemovable               | 1            | 00          | all devices removable  |
| 8              | PortPwrCtrlMask               | 1            | FF          | must be all ones for compatibility with <i>USB Specification Rev. 1.0</i>                          |

[1] ISP1122 always reports power management status on an individual basis, even for ganged/global modes. This is compliant with *USB Specification Rev. 1.1*.

[2] Condition with no overcurrent detection is reported to the host.

[3] Value in units of 2 ms.

**Table 15: String descriptors**

String descriptors are optional and therefore disabled by default; they can be enabled through an external EEPROM.

| Offset (bytes)                                    | Field name      | Size (bytes) | Value (Hex)       | Comments                     |
|---|-----------------|--------------|-------------------|------------------------------|
| <b>String descriptor (0): language ID string</b>  |                 |              |                   |                              |
| 0   | bLength         | 1            | 04                | descriptor length = 4 bytes  |
| 1   | bDescriptorType | 1            | 03                | type = STRING                |
| 2   | bString         | 2            | 09, 04            | LANGID code zero             |
| <b>String descriptor (1): manufacturer string</b> |                 |              |                   |                              |
| 0   | bLength         | 1            | 2E                | descriptor length = 46 bytes |
| 1   | bDescriptorType | 1            | 03                | type = STRING                |
| 2   | bString         | 44           | UC <sup>[1]</sup> | "Philips Semiconductors"     |
| <b>String descriptor (2): product string</b>      |                 |              |                   |                              |
| 0   | bLength         | 1            | 10                | descriptor length = 16 bytes |
| 1   | bDescriptorType | 1            | 03                | type = STRING                |
| 2   | bString         | 14           | UC <sup>[1]</sup> | "ISP1122"                    |

[1] Unicode encoded string.

## 9.4 Hub responses

This section describes the hub responses to requests from the USB host.

### 9.4.1 Get device status

The hub returns 2 bytes, see [Table 16](#).

**Table 16: Get device status response**

| Bit #   | Function       | Value | Description            |
|---------|----------------|-------|------------------------|
| 0       | self-powered   | 0     | bus-powered            |
|         |                | 1     | self-powered           |
| 1       | remote wake-up | 0     | no remote wake-up      |
|         |                | 1     | remote wake-up enabled |
| 2 to 15 | reserved       | 0     | -                      |

### 9.4.2 Get configuration

The hub returns 1 byte, see [Table 17](#).

**Table 17: Get configuration response**

| Bit #  | Function            | Value | Description           |
|--------|---------------------|-------|-----------------------|
| 0      | configuration value | 0     | device not configured |
|        |                     | 1     | device configured     |
| 1 to 7 | reserved            | 0     | -                     |

### 9.4.3 Get interface status

The hub returns 2 bytes, see [Table 18](#).

**Table 18: Get interface status response**

| Bit #   | Function | Value | Description |
|---------|----------|-------|-------------|
| 0 to 15 | reserved | 0     | -           |

### 9.4.4 Get hub status

The hub returns 4 bytes, see [Table 19](#).

**Table 19: Get hub status response**

| Bit #    | Function                     | Value | Description                        |
|----------|------------------------------|-------|------------------------------------|
| 0        | local power source           | 0     | local power supply good            |
|          |                              | 1     | local power supply lost            |
| 1        | overcurrent indicator        | 0     | no overcurrent condition           |
|          |                              | 1     | hub overcurrent condition detected |
| 2 to 15  | reserved                     | 0     | -                                  |
| 16       | local power status change    | 0     | no change in local power status    |
|          |                              | 1     | local power status changed         |
| 17       | overcurrent indicator change | 0     | no change in overcurrent condition |
|          |                              | 1     | overcurrent condition changed      |
| 18 to 31 | reserved                     | 0     | -                                  |

### 9.4.5 Get port status

The hub returns 4 bytes. The first 2 bytes contain the port status bits (wPortStatus, see Table 20). The last 2 bytes hold the port status change bits (wPortChange, see Table 21).

**Table 20: Get port status response (wPortStatus)**

| Bit #    | Function                  | Value | Description                    |
|----------|---------------------------|-------|--------------------------------|
| 0        | current connect status    | 0     | no device present              |
|          |                           | 1     | device present on this port    |
| 1        | port enabled/disabled     | 0     | port disabled                  |
|          |                           | 1     | port enabled                   |
| 2        | suspend                   | 0     | port not suspended             |
|          |                           | 1     | port suspended                 |
| 3        | overcurrent indicator     | 0     | no overcurrent condition       |
|          |                           | 1     | overcurrent condition detected |
| 4        | reset                     | 0     | reset not asserted             |
|          |                           | 1     | reset asserted                 |
| 5 to 7   | reserved                  | 0     | -                              |
| 8        | port power                | 0     | port powered off               |
|          |                           | 1     | port power on                  |
| 9        | low-speed device attached | 0     | full-speed device attached     |
|          |                           | 1     | low-speed device attached      |
| 10 to 15 | reserved                  | 0     | -                              |

**Table 21: Get port status response (wPortChange)**

| Bit #   | Function                     | Value | Description                         |
|---------|------------------------------|-------|-------------------------------------|
| 0       | connect status change        | 0     | no change in current connect status |
|         |                              | 1     | current connect status changed      |
| 1       | port enabled/disabled change | 0     | no port error                       |
|         |                              | 1     | port disabled by a port error       |
| 2       | suspend change               | 0     | no change in suspend status         |
|         |                              | 1     | resume complete                     |
| 3       | overcurrent indicator change | 0     | no change in overcurrent status     |
|         |                              | 1     | overcurrent indicator changed       |
| 4       | reset change                 | 0     | no change in reset status           |
|         |                              | 1     | reset complete                      |
| 5 to 15 | reserved                     | 0     | -                                   |

#### 9.4.6 Get configuration descriptor

The hub returns 25 bytes containing the configuration descriptor (9 bytes, see [Table 11](#)), the interface descriptor (9 bytes, see [Table 12](#)) and the endpoint descriptor (7 bytes, see [Table 13](#)).

#### 9.4.7 Get device descriptor

The hub returns 18 bytes containing the device descriptor, see [Table 10](#).

#### 9.4.8 Get hub descriptor

The hub returns 9 bytes containing the hub descriptor, see [Table 14](#).

#### 9.4.9 Get string descriptor (0)

The hub returns 4 bytes containing the language ID, see [Table 15](#).

#### 9.4.10 Get string descriptor (1)

The hub returns 46 bytes containing the manufacturer name, see [Table 15](#).

#### 9.4.11 Get string descriptor (2)

The hub returns 16 bytes containing the product name, see [Table 15](#).

## 10. I<sup>2</sup>C-bus interface

A simple I<sup>2</sup>C-bus interface is provided in the ISP1122 to read customized vendor ID, product ID and some other configuration bits from an external EEPROM. The interface supports single master operation at a nominal bus speed of 93.75 kHz.

The I<sup>2</sup>C-bus interface is intended for bidirectional communication between ICs via two serial bus wires, SDA (data) and SCL (clock). Both lines are driven by open-drain circuits and must be connected to the positive supply voltage via pull-up resistors.

### 10.1 Protocol

The I<sup>2</sup>C-bus protocol defines the following conditions:

- **Bus free:** both SDA and SCL are HIGH
- **START:** a HIGH-to-LOW transition on SDA, while SCL is HIGH
- **STOP:** a LOW-to-HIGH transition on SDA, while SCL is HIGH
- **Data valid:** after a START condition, data on SDA are stable during the HIGH period of SCL; data on SDA may only change while SCL is LOW.

Each device on the I<sup>2</sup>C-bus has a unique slave address, which the master uses to select a device for access.

The master starts a data transfer using a START condition and ends it by generating a STOP condition. Transfers can only be initiated when the bus is free. The receiver must acknowledge each byte by means of a LOW level on SDA during the ninth clock pulse on SCL.

For detailed information please consult *The I<sup>2</sup>C-bus and how to use it.*, order number 9398 393 40011.

### 10.2 Hardware connections

Via the I<sup>2</sup>C-bus interface the ISP1122 can be connected to an external EEPROM (PCF8582 or equivalent). The hardware connections are shown in [Figure 5](#).

The SCL and SDA pins are multiplexed with pins OPTION and INDV respectively.

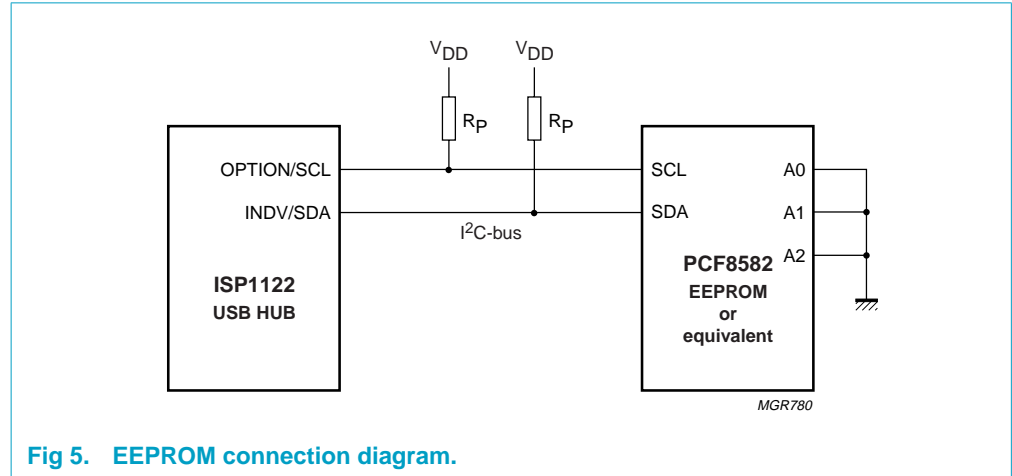


Fig 5. EEPROM connection diagram.

The slave address which ISP1122 uses to access the EEPROM is 1010000B. Page mode addressing is not supported, so pins A0, A1 and A2 of the EEPROM must be connected to GND (logic 0).

### 10.3 Data transfer

When the ISP1122 is reset, the I<sup>2</sup>C-bus interface tries to read 6 bytes of configuration data from an external EEPROM. If no response is detected, the levels on inputs SDA and SCL are interpreted as INDV and OPTION to select the operating mode (see [Table 4](#)).

The data in the EEPROM memory are organized as shown in [Table 22](#).

Table 22: EEPROM organization

| Address (Hex) | Default value (Hex) | Contents  |
|---------------|---------------------|---|
| 00            | CC                  | idVendor <sup>[1]</sup> (lower byte)                      |
| 01            | 04                  | idVendor <sup>[1]</sup> (upper byte)                      |
| 02            | 22                  | idProduct <sup>[2]</sup> (lower byte)                     |
| 03            | 11                  | idProduct <sup>[2]</sup> (upper byte)                     |
| 04            | -                   | configuration bits C7 to C0; see <a href="#">Table 23</a> |
| 05            | AA                  | signature   |

[1] Vendor ID code in the Device descriptor, see [Table 10](#).

[2] Product ID code in the Device descriptor, see [Table 10](#).

Table 23: Configuration bits

| Bit    | Function                                     | Value (Bin)                  | Description  |
|--------|--|------------------------------|--|
| C0     | OPTION                                       | see Table 4 “Mode selection” |  |
| C1     | INDV   | see Table 4 “Mode selection” |  |
| C2     | reserved                                     | 0 <sup>[1]</sup>             | must always be programmed to logic 0   |
| C3     | PwrOn2PwrGood <sup>[2]</sup>                 | 0 <sup>[1]</sup>             | 100 ms (bPwrOn2PwrGood = 32H)  |
|        |  | 1                            | 500 ms (bPwrOn2PwrGood = FAH)  |
| C4     | string descriptor enable                     | 0 <sup>[1]</sup>             | string descriptors disabled  |
|        |  | 1                            | string descriptors enabled (strings: “Philips Semiconductors”, “ISP1122”)  |
| C5     | internal analog overcurrent detection enable | 0                            | internal analog overcurrent detection circuit disabled; overcurrent pins $\overline{OCn}$ function as digital inputs (TTL level) |
|        |  | 1 <sup>[1]</sup>             | internal analog overcurrent detection circuit enabled  |
| C7, C6 | MaxPower <sup>[3]</sup>                      | 00 <sup>[1]</sup>            | 100 mA (MaxPower = 32H)  |
|        |  | 1X                           | 500 mA (MaxPower = FAH)  |
|        |  | 01                           | 0 mA (MaxPower = 00H)  |

[1] Default value at reset if no external EEPROM is present.

[2] Modifies the Hub Descriptor field ‘bPwrOn2PwrGood’, see Table 14.

[3] Modifies the Hub Descriptor field ‘MaxPower’, see Table 14.

## 11. Hub power modes

USB hubs can either be self-powered or bus-powered.

**Self-powered** — Self-powered hubs have a 5 V local power supply on board which provide power to the hub and the downstream ports. The *USB Specification Rev. 1.1* requires that these hubs limit the current to 500 mA per downstream port and report overcurrent conditions to the host. The hub may optionally draw 100 mA from the USB supply ( $V_{BUS}$ ) to power the interface functions (**hybrid-powered**).

**Bus-powered** — Bus-powered hubs obtain all power from the host or an upstream self-powered hub. The maximum current is 100 mA per downstream port. Current limiting and reporting of overcurrent conditions are both optional.

Power switching of downstream ports can be done **individually** or **ganged**, where all ports are switched simultaneously with one power switch. The ISP1122 supports both modes, which can be selected using input INDV (see Table 4).

### 11.1 Voltage drop requirements

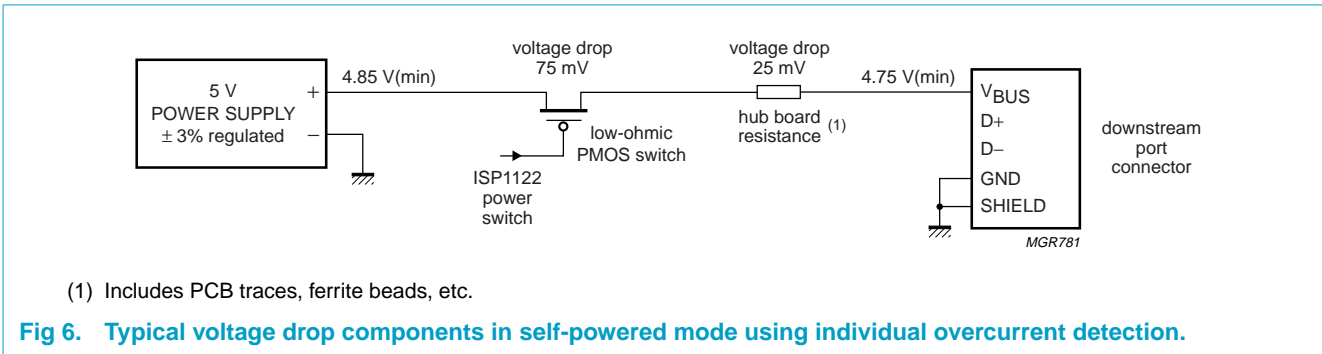
#### 11.1.1 Self-powered hubs

Self-powered hubs are required to provide a minimum of 4.75 V to its output port connectors at all legal load conditions. To comply with Underwriters Laboratory Inc. (UL) safety requirements, the power from any port must be limited to 25 W (5 A at 5 V). Overcurrent protection may be implemented on a global or individual basis.

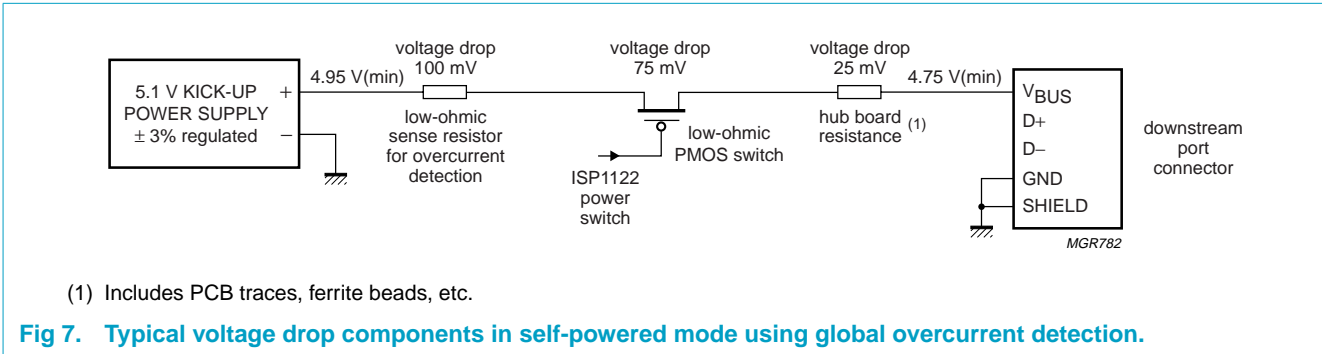
Assuming a  $5\text{ V} \pm 3\%$  power supply the worst case supply voltage is  $4.85\text{ V}$ . This only allows a voltage drop of  $100\text{ mV}$  across the hub printed-circuit board (PCB) to each downstream connector. This includes a voltage drop across:

- Power supply connector
- Hub PCB (power and ground traces, ferrite beads)
- Power switch (FET on-resistance)
- Overcurrent sense device.

PCB resistance and power supply connector resistance may cause a drop of  $25\text{ mV}$ , leaving only  $75\text{ mV}$  as the voltage drop allowed across the power switch and overcurrent sense device. The individual voltage drop components are shown in **Figure 6**.



In case of global overcurrent detection an increased voltage drop is needed for the overcurrent sense device (in this case a low-ohmic resistor). This can be realized by using a special power supply of  $5.1\text{ V} \pm 3\%$ , as shown in **Figure 7**.



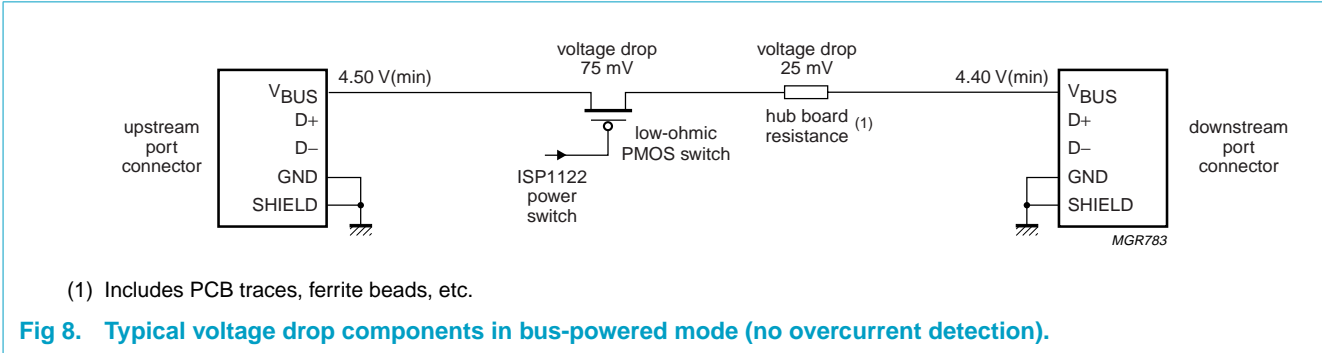
**11.1.2 Bus-powered hubs**

Bus-powered hubs are guaranteed to receive a supply voltage of  $4.5\text{ V}$  at the upstream port connector and must provide a minimum of  $4.4\text{ V}$  to the downstream port connectors. The voltage drop of  $100\text{ mV}$  across bus-powered hubs includes:

- Hub PCB (power and ground traces, ferrite beads)
- Power switch (FET on-resistance)
- Overcurrent sense device.

The PCB resistance may cause a drop of 25 mV, which leaves 75 mV for the power switch and overcurrent sense device. The voltage drop components are shown in [Figure 8](#).

For bus-powered hubs overcurrent protection is optional. It may be implemented for all downstream ports on a global or individual basis.



## 12. Overcurrent detection

The ISP1122 has an analog overcurrent detection circuit for monitoring downstream port lines. This circuit automatically reports an overcurrent condition to the host and turns off the power to the faulty port. The host must reset the condition flag.

Pins  $\overline{OC1}$  to  $\overline{OC5}/\overline{GOC}$  are used for individual port overcurrent detection. Pin  $\overline{OC5}/\overline{GOC}$  can also be used for global overcurrent detection. This is controlled by input INDV (see [Table 4](#)).

The overcurrent detection circuit can be switched off using an external EEPROM (see [Table 23](#)). In this case, the overcurrent pins  $\overline{OCn}$  function as logic inputs (TTL level).

### 12.1 Overcurrent circuit description

The integrated overcurrent detection circuit of ISP1122 senses the voltage drop across the power switch or an extra low-ohmic sense resistor. When the port draws too much current, the voltage drop across the power switch exceeds the trip voltage threshold ( $\Delta V_{trip}$ ). The overcurrent circuit detects this and switches off the power switch control signal after a delay of 15 ms ( $t_{trip}$ ). This delay acts as a ‘debounce’ period to minimize false tripping, especially during the inrush current produced by ‘hot plugging’ of a USB device.

### 12.2 Power switch selection

From the voltage drop analysis given in [Figure 6](#), [Figure 7](#) and [Figure 8](#), the power switch has a voltage drop budget of 75 mV. For individual self-powered mode, the current drawn per port can be up to 500 mA. Thus the power switch should have maximum on-resistance of 150 mΩ.

If the voltage drop due to the hub board resistance can be minimized, the power switch can have more voltage drop budget and therefore a higher on-resistance. Power switches with a typical on-resistance of around 100 mΩ fit into this application.



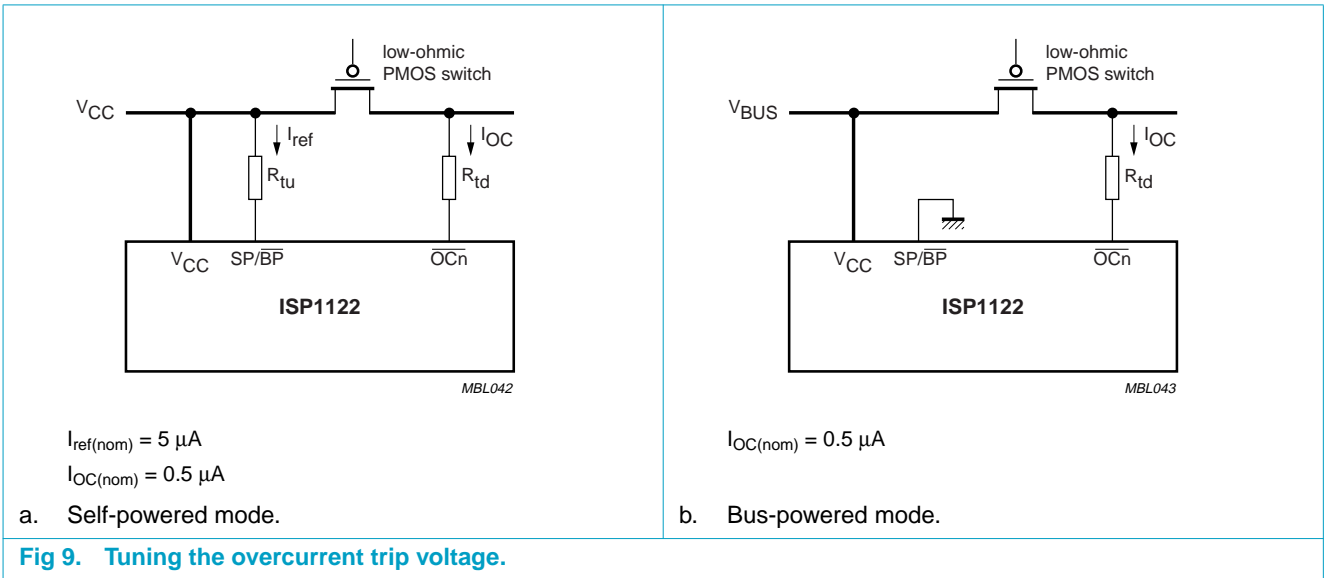
The ISP1122 overcurrent detection circuit has been designed with a nominal trip voltage ( $\Delta V_{trip}$ ) of 85 mV. This gives a typical trip current of approximately 850 mA for a power switch with an on-resistance of 100 m $\Omega$ <sup>1</sup>.

### 12.3 Tuning the overcurrent trip voltage

The ISP1122 trip voltage can optionally be adjusted through external components to set the desired trip current. This is done by inserting tuning resistors at pins SP/ $\overline{BP}$  or  $\overline{OCn}$  (see Figure 9).  $R_{tu}$  tunes up the trip voltage  $\Delta V_{trip}$  and  $R_{td}$  tunes it down according to Equation 1.

$$\Delta V_{trip} = \Delta V_{trip(intrinsic)} + I_{ref} \cdot R_{tu} - I_{OC} \cdot R_{td} \tag{1}$$

with  $I_{ref(nom)} = 5 \mu A$  and  $I_{OC(nom)} = 0.5 \mu A$ .

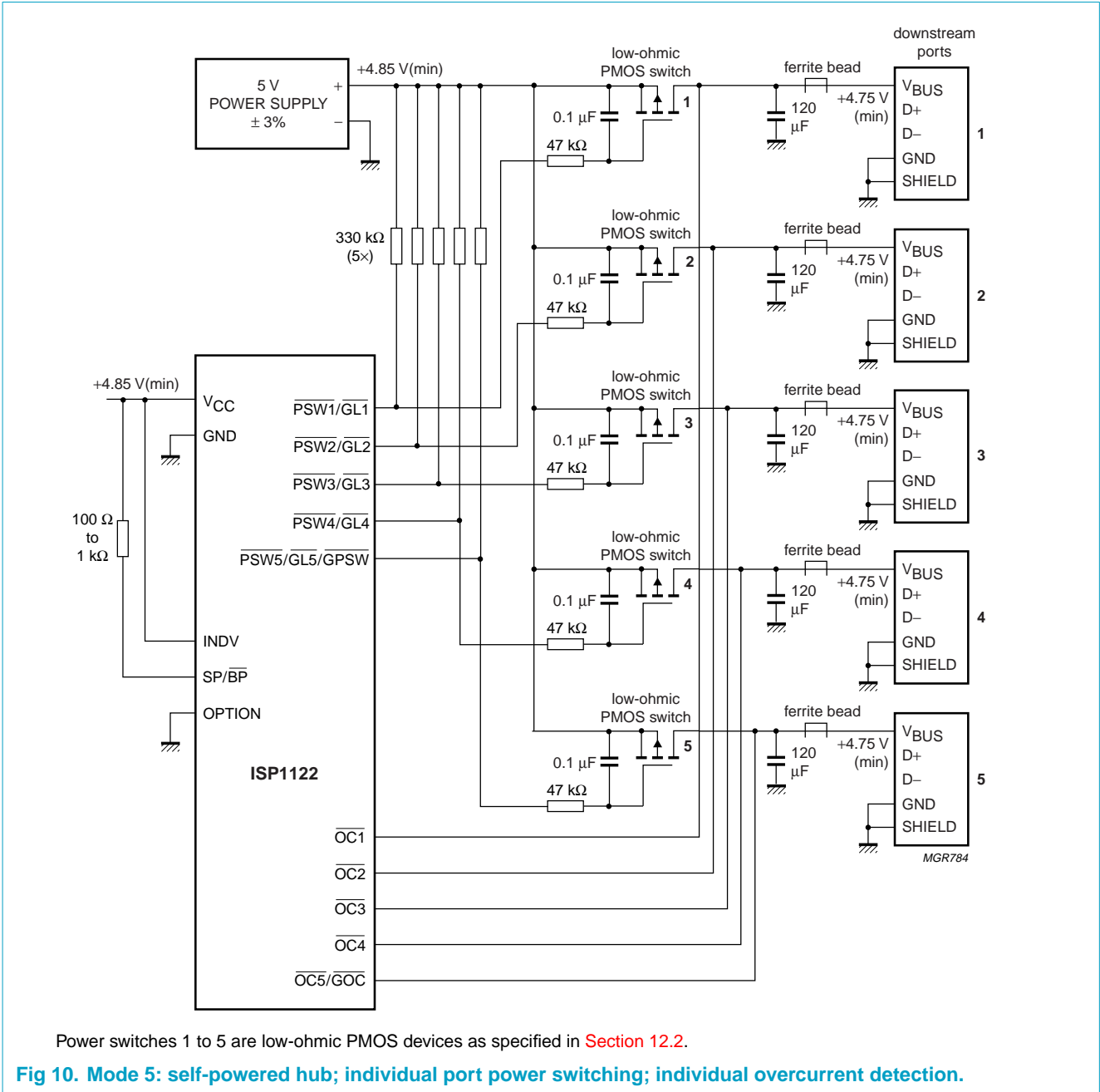


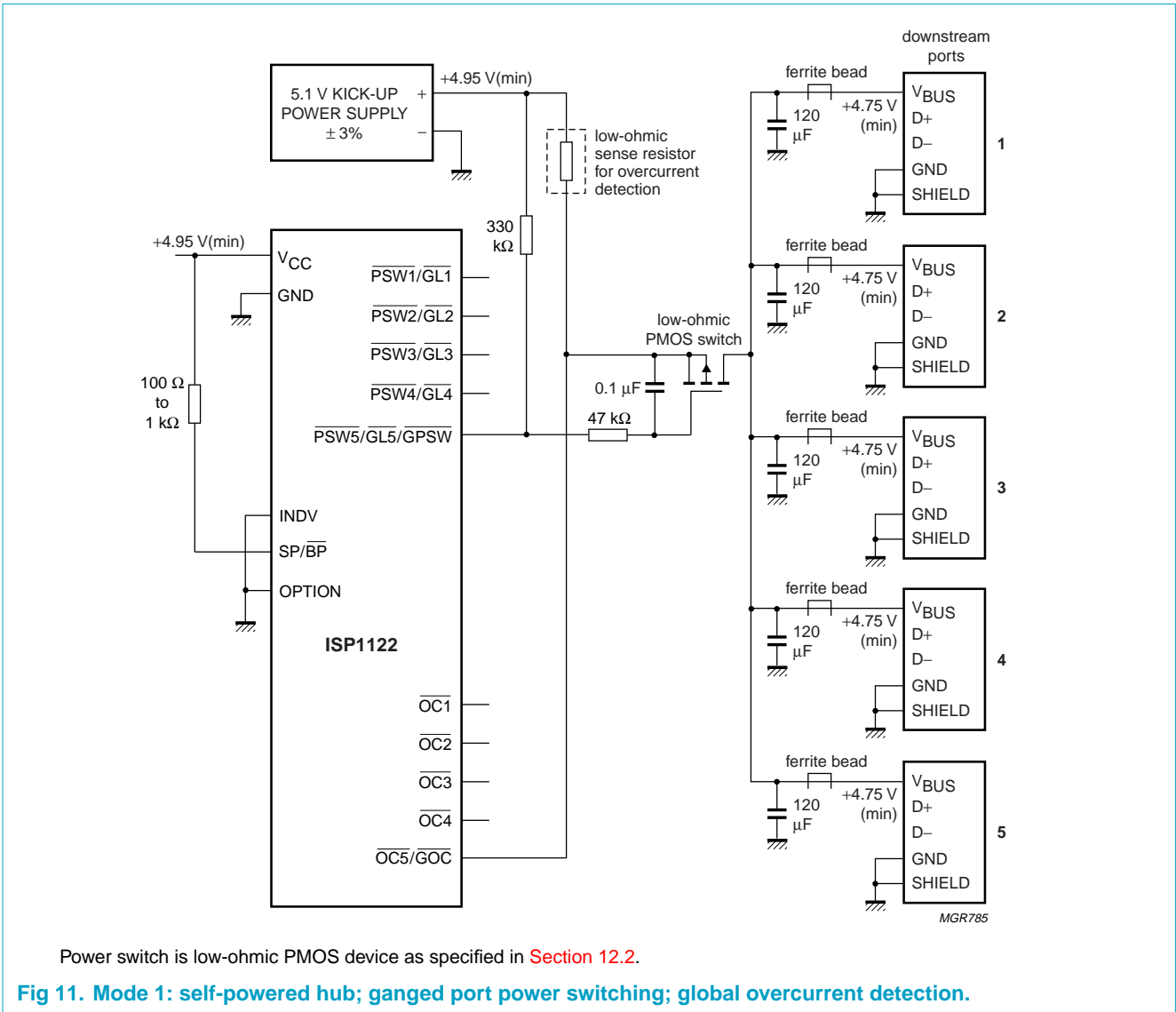
### 12.4 Reference circuits

Some typical examples of port power switching and overcurrent detection modes are given in Figure 10 to Figure 13.

The RC circuit (47 k $\Omega$  and 0.1  $\mu F$ ) around the PMOS switch provides for soft turn-on. The series resistor connecting the SP/ $\overline{BP}$  pin to  $V_{CC}$  tunes up the overcurrent trip voltage slightly (see Figure 9). In the schematic diagram the resistor separates the net names for pins  $V_{CC}$  and SP/ $\overline{BP}$ . This allows an automatic router to use a wide trace for  $V_{CC}$  and a narrow trace to connect pin SP/ $\overline{BP}$ .

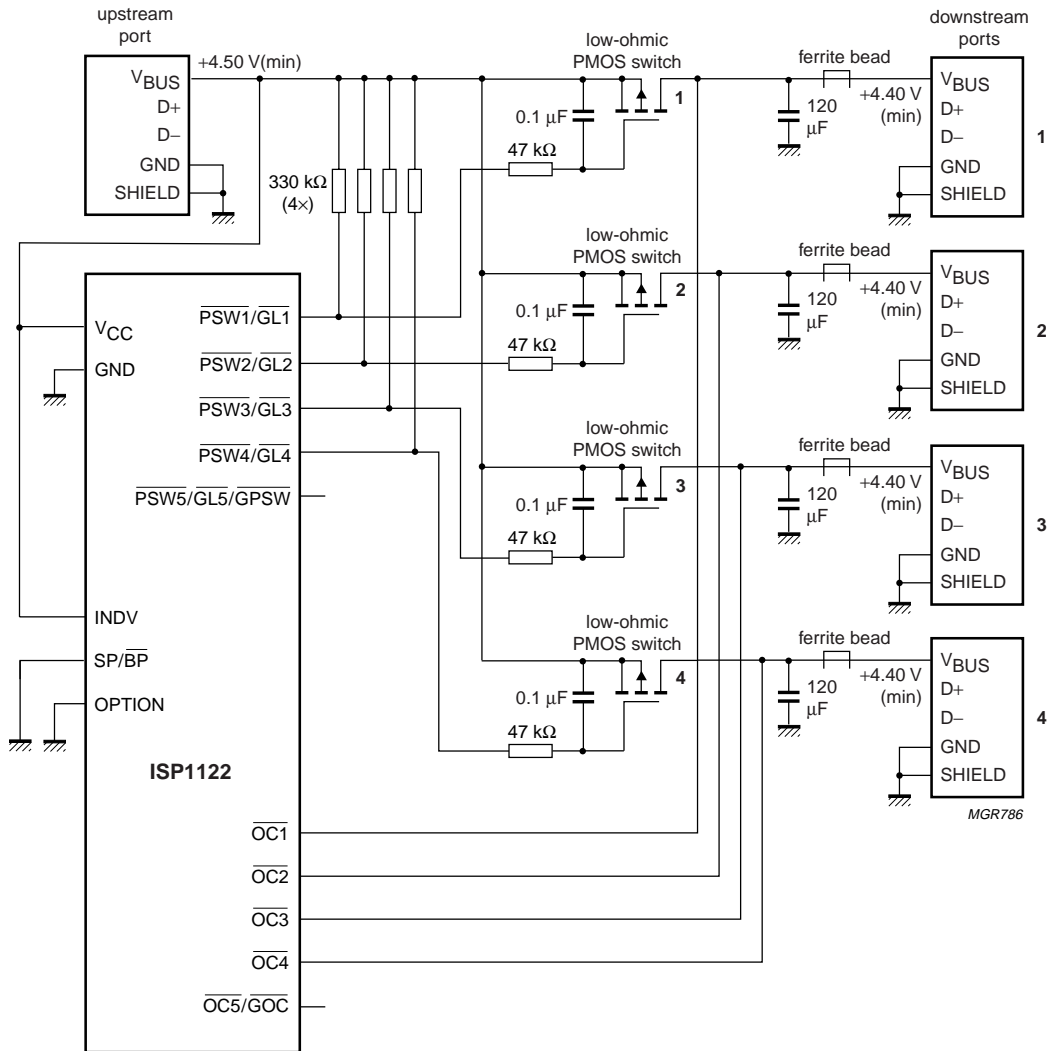
1. The following PMOS power switches have been tested to work well with the ISP1122: Philips PHP109, Vishay Siliconix Si2301DS, Fairchild FDN338P.





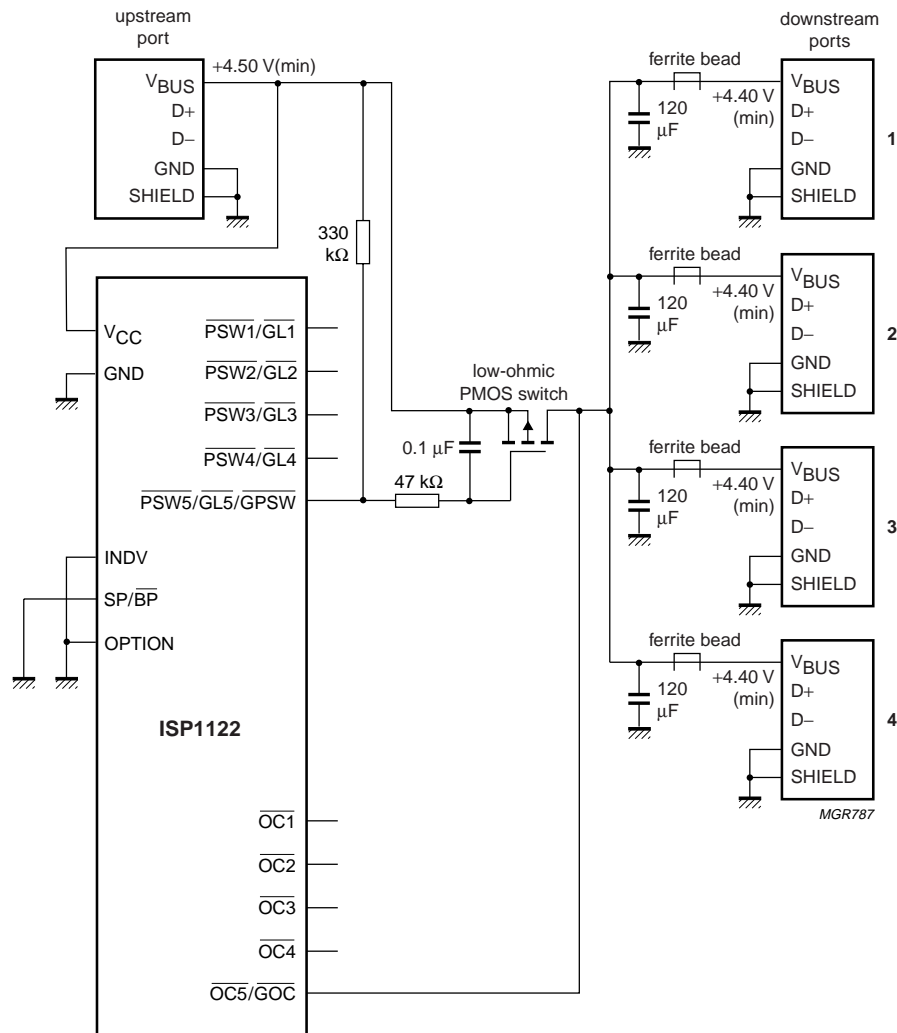
Power switch is low-ohmic PMOS device as specified in Section 12.2.

Fig 11. Mode 1: self-powered hub; ganged port power switching; global overcurrent detection.



Power switches 1 to 4 are low-ohmic PMOS devices as specified in [Section 12.2](#).

**Fig 12. Mode 4: bus-powered hub; individual port power switching; individual overcurrent detection.**



Power switch is low-ohmic PMOS device as specified in Section 12.2.

**Fig 13. Mode 0: bus-powered hub; ganged port power switching; global overcurrent detection.**

## 13. Limiting values

**Table 24: Absolute maximum ratings**

In accordance with the Absolute Maximum Rating System (IEC 60134).

| Symbol        | Parameter                       | Conditions                  | Min      | Max            | Unit |
|---------------|---------------------------------|-----------------------------|----------|----------------|------|
| $V_{CC}$      | supply voltage                  |                             | -0.5     | +6.0           | V    |
| $V_I$         | input voltage                   |                             | -0.5     | $V_{CC} + 0.5$ | V    |
| $I_{latchup}$ | latchup current                 | $V_I < 0$ or $V_I > V_{CC}$ | -        | 200            | mA   |
| $V_{esd}$     | electrostatic discharge voltage | $I_{LI} < 15 \mu A$         | [1][2] - | $\pm 4000$ [3] | V    |
| $T_{stg}$     | storage temperature             |                             | -60      | +150           | °C   |
| $P_{tot}$     | total power dissipation         |                             | -        | 95             | mW   |

[1] Equivalent to discharging a 100 pF capacitor via a 1.5 k $\Omega$  resistor (Human Body Model).

[2] Values are given for device only; in-circuit  $V_{esd(max)} = \pm 8000$  V.

[3] For open-drain pins  $V_{esd(max)} = \pm 2000$  V.

**Table 25: Recommended operating conditions**

| Symbol        | Parameter                                | Conditions | Min | Max | Unit |
|---------------|--|------------|-----|-----|------|
| $V_{CC}$      | supply voltage                           |            | 4.0 | 5.5 | V    |
| $V_I$         | input voltage                            |            | 0   | 5.5 | V    |
| $V_{I(AI/O)}$ | input voltage on analog I/O pins (D+/D-) |            | 0   | 3.6 | V    |
| $V_{O(od)}$   | open-drain output pull-up voltage        |            | 0   | 5.5 | V    |
| $T_{amb}$     | operating ambient temperature            |            | -40 | +85 | °C   |

## 14. Static characteristics

**Table 26: Static characteristics; supply pins**

$V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C; unless otherwise specified.

| Symbol         | Parameter                | Conditions   | Min     | Typ | Max | Unit    |
|----------------|--------------------------|--|---------|-----|-----|---------|
| $V_{reg(3.3)}$ | regulated supply voltage |  | 3.0 [1] | 3.3 | 3.6 | V       |
| $I_{CC}$       | operating supply current |  | -       | 18  | -   | mA      |
| $I_{CC(susp)}$ | suspend supply current   | 1.5 k $\Omega$ pull-up on upstream port D+ (pin DP0) | -       | -   | 270 | $\mu$ A |
|                |                          | no pull-up on upstream port D+ (pin DP0)             | -       | -   | 80  | $\mu$ A |

[1] In 'suspend' mode the minimum voltage is 2.7 V.

**Table 27: Static characteristics: digital pins**

$V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C; unless otherwise specified.

| Symbol                        | Parameter                                     | Conditions            | Min | Typ | Max     | Unit    |
|-------------------------------|---|-----------------------|-----|-----|---------|---------|
| <b>Input levels</b>           |   |                       |     |     |         |         |
| $V_{IL}$                      | LOW-level input voltage                       |                       | -   | -   | 0.8     | V       |
| $V_{IH}$                      | HIGH-level input voltage                      |                       | 2.0 | -   | -       | V       |
| <b>Schmitt trigger inputs</b> |   |                       |     |     |         |         |
| $V_{th(LH)}$                  | positive-going threshold voltage              |                       | 1.4 | -   | 1.9     | V       |
| $V_{th(HL)}$                  | negative-going threshold voltage              |                       | 0.9 | -   | 1.5     | V       |
| $V_{hys}$                     | hysteresis voltage                            |                       | 0.4 | -   | 0.7     | V       |
| <b>Output levels</b>          |   |                       |     |     |         |         |
| $V_{OL}$                      | LOW-level output voltage (open drain outputs) | $I_{OL} = 6$ mA       | -   | -   | 0.4     | V       |
|                               |   | $I_{OL} = 20$ $\mu$ A | -   | -   | 0.1     | V       |
| <b>Leakage current</b>        |   |                       |     |     |         |         |
| $I_{LI}$                      | input leakage current                         |                       | -   | -   | $\pm 1$ | $\mu$ A |
| <b>Open-drain outputs</b>     |   |                       |     |     |         |         |
| $I_{OZ}$                      | OFF-state output current                      |                       | -   | -   | $\pm 1$ | $\mu$ A |

**Table 28: Static characteristics: overcurrent sense pins**

$V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C; unless otherwise specified.

| Symbol            | Parameter   | Conditions                                      | Min | Typ | Max | Unit |
|-------------------|---|---|-----|-----|-----|------|
| $\Delta V_{trip}$ | overcurrent detection trip voltage on $\overline{OCn}$ pins | $\Delta V = V_{CC} - V_{\overline{OCn}}$ [1]    | 65  | 85  | 105 | mV   |
|                   |   | $\Delta V = V_{SP/BP} - V_{\overline{OCn}}$ [2] |     |     |     |      |

[1] Bus-powered mode.

[2] Self-powered or hybrid-powered mode.

**Table 29: Static characteristics: analog I/O pins (D+, D-)** [1] $V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C; unless otherwise specified.

| Symbol                 | Parameter  | Conditions                      | Min     | Typ | Max      | Unit       |
|------------------------|--|---------------------------------|---------|-----|----------|------------|
| <b>Input levels</b>    |  |                                 |         |     |          |            |
| $V_{DI}$               | differential input sensitivity                             | $ V_{I(D+)} - V_{I(D-)} $       | 0.2     | -   | -        | V          |
| $V_{CM}$               | differential common mode voltage                           | includes $V_{DI}$ range         | 0.8     | -   | 2.5      | V          |
| $V_{IL}$               | LOW-level input voltage                                    |                                 | -       | -   | 0.8      | V          |
| $V_{IH}$               | HIGH-level input voltage                                   |                                 | 2.0     | -   | -        | V          |
| <b>Output levels</b>   |  |                                 |         |     |          |            |
| $V_{OL}$               | LOW-level output voltage                                   | $R_L = 1.5$ k $\Omega$ to +3.6V | -       | -   | 0.3      | V          |
| $V_{OH}$               | HIGH-level output voltage                                  | $R_L = 15$ k $\Omega$ to GND    | 2.8     | -   | 3.6      | V          |
| <b>Leakage current</b> |  |                                 |         |     |          |            |
| $I_{LZ}$               | OFF-state leakage current                                  |                                 | -       | -   | $\pm 10$ | $\mu$ A    |
| <b>Capacitance</b>     |  |                                 |         |     |          |            |
| $C_{IN}$               | transceiver capacitance                                    | pin to GND                      | -       | -   | 20       | pF         |
| <b>Resistance</b>      |  |                                 |         |     |          |            |
| $Z_{DRV}$ [2]          | driver output impedance                                    | steady-state drive              | 28      | -   | 44       | $\Omega$   |
| $Z_{INP}$              | input impedance  |                                 | 10      | -   | -        | M $\Omega$ |
| <b>Termination</b>     |  |                                 |         |     |          |            |
| $V_{TERM}$ [3]         | termination voltage for upstream port pull-up ( $R_{PU}$ ) |                                 | 3.0 [4] | -   | 3.6      | V          |

[1] D+ is the USB positive data pin (DPn); D- is the USB negative data pin (DMn).

[2] Includes external resistors of  $20 \Omega \pm 1\%$  on both D+ and D-.[3] This voltage is available at pin  $V_{reg(3.3)}$ .

[4] In 'suspend' mode the minimum voltage is 2.7 V.

## 15. Dynamic characteristics

**Table 30: Dynamic characteristics** $V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C; unless otherwise specified.

| Symbol                    | Parameter                               | Conditions                 | Min | Typ   | Max | Unit    |
|---------------------------|---|----------------------------|-----|-------|-----|---------|
| <b>Reset</b>              |   |                            |     |       |     |         |
| $t_{W(\overline{RESET})}$ | pulse width on input $\overline{RESET}$ | crystal oscillator running | 10  | -     | -   | $\mu$ s |
|                           |   | crystal oscillator stopped | -   | 2 [1] | -   | ms      |
| <b>Crystal oscillator</b> |   |                            |     |       |     |         |
| $f_{XTAL}$                | crystal frequency                       |                            | -   | 6     | -   | MHz     |

[1] Dependent on the crystal oscillator start-up time.



**Table 31: Dynamic characteristics: overcurrent sense pins**

$V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C; unless otherwise specified.

| Symbol     | Parameter  | Conditions    | Min   | Typ | Max | Unit |
|------------|--|---------------|-------|-----|-----|------|
| $t_{trip}$ | overcurrent trip response time from $\overline{OCn}$ LOW to $\overline{PSWn}$ HIGH | see Figure 14 | [1] - | -   | 15  | ms   |

[1] Operating modes 0, 1, 4 and 5; see Table 4.

**Table 32: Dynamic characteristics: analog I/O pins (D+, D-); full-speed mode [1]**

$V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C;  $C_L = 50$  pF;  $R_{PU} = 1.5$  k $\Omega$  on D+ to  $V_{TERM}$ ; unless otherwise specified.

| Symbol  | Parameter  | Conditions   | Min         | Typ | Max    | Unit |
|---|--|--|-------------|-----|--------|------|
| <b>Driver characteristics</b>                                 |  |  |             |     |        |      |
| $t_{FR}$  | rise time  | $C_L = 50$ pF;<br>10 to 90% of $ V_{OH} - V_{OL} $ | 4           | -   | 20     | ns   |
| $t_{FF}$  | fall time  | $C_L = 50$ pF;<br>10 to 90% of $ V_{OH} - V_{OL} $ | 4           | -   | 20     | ns   |
| FRFM  | differential rise/fall time matching ( $t_{FR}/t_{FF}$ )   |  | [2] 90      | -   | 111.11 | %    |
| $V_{CRS}$   | output signal crossover voltage                            |  | [2][3] 1.3  | -   | 2.0    | V    |
| <b>Data source timing</b>                                     |  |  |             |     |        |      |
| $t_{DJ1}$   | source differential jitter for consecutive transitions     | see Figure 15                                      | [2][3] -3.5 | -   | +3.5   | ns   |
| $t_{DJ2}$   | source differential jitter for paired transitions          | see Figure 15                                      | [2][3] -4   | -   | +4     | ns   |
| $t_{FEOPT}$   | source EOP width   | see Figure 16                                      | [3] 160     | -   | 175    | ns   |
| $t_{FDEOP}$   | source differential data-to-EOP transition skew            | see Figure 16                                      | [3] -2      | -   | +5     | ns   |
| <b>Receiver timing</b>  |  |  |             |     |        |      |
| $t_{JR1}$   | receiver data jitter tolerance for consecutive transitions | see Figure 17                                      | [3] -18.5   | -   | +18.5  | ns   |
| $t_{JR2}$   | receiver data jitter tolerance for paired transitions      | see Figure 17                                      | [3] -9      | -   | +9     | ns   |
| $t_{FEOPR}$   | receiver SE0 width   | accepted as EOP;<br>see Figure 16                  | [3] 82      | -   | -      | ns   |
| $t_{FST}$   | width of SE0 during differential transition                | rejected as EOP;<br>see Figure 18                  | [3] -       | -   | 14     | ns   |
| <b>Hub timing (downstream ports configured as full-speed)</b> |  |  |             |     |        |      |
| $t_{FHDD}$  | hub differential data delay (without cable)                | see Figure 19;<br>$C_L = 0$ pF                     | [3] -       | -   | 44     | ns   |
| $t_{FSOP}$  | data bit width distortion after SOP                        | see Figure 19                                      | [3] -5      | -   | +5     | ns   |
| $t_{FEOPD}$   | hub EOP delay relative to $t_{HDD}$                        | see Figure 20                                      | [3] 0       | -   | 15     | ns   |
| $t_{FHESK}$   | hub EOP output width skew                                  | see Figure 20                                      | [3] -15     | -   | +15    | ns   |

[1] Test circuit: see Figure 22.

[2] Excluding the first transition from Idle state.

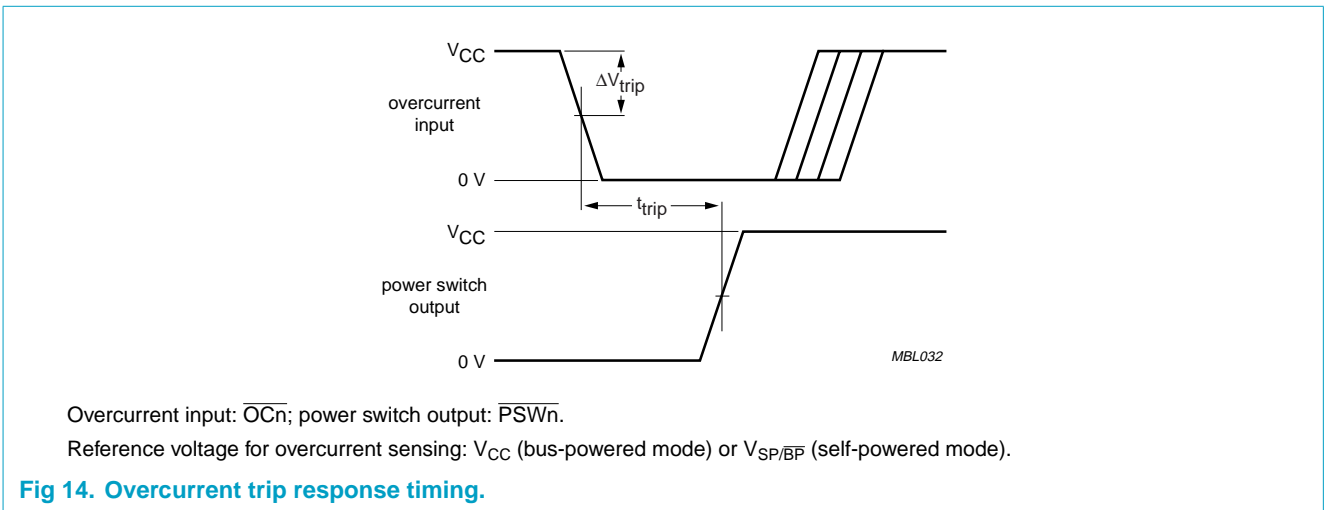
[3] Characterized only, not tested. Limits guaranteed by design.

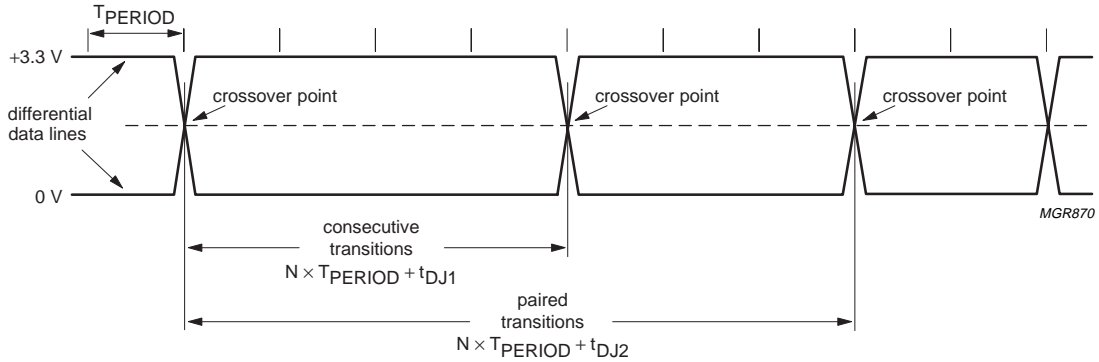
**Table 33: Dynamic characteristics: analog I/O pins (D+, D-); low-speed mode<sup>[1]</sup>**

$V_{CC} = 4.0$  to  $5.5$  V;  $V_{GND} = 0$  V;  $T_{amb} = -40$  to  $+85$  °C;  $C_L = 50$  pF;  $R_{PU} = 1.5$  k $\Omega$  on D- to  $V_{TERM}$ ; unless otherwise specified.

| Symbol   | Parameter  | Conditions   | Min        | Typ | Max  | Unit |
|--|--|--|------------|-----|------|------|
| <b>Driver characteristics</b>                                |  |  |            |     |      |      |
| $t_{LR}$   | rise time  | $C_L = 200$ to $600$ pF;<br>10 to 90% of $ V_{OH} - V_{OL} $ | 75         | -   | 300  | ns   |
| $t_{LF}$   | fall time  | $C_L = 200$ to $600$ pF;<br>10 to 90% of $ V_{OH} - V_{OL} $ | 75         | -   | 300  | ns   |
| LRFM   | differential rise/fall time matching ( $t_{LR}/t_{LF}$ ) |  | [2] 80     | -   | 125  | %    |
| $V_{CRS}$  | output signal crossover voltage                          |  | [2][3] 1.3 | -   | 2.0  | V    |
| <b>Hub timing (downstream ports configured as low-speed)</b> |  |  |            |     |      |      |
| $t_{LHDD}$   | hub differential data delay                              | see Figure 19  | -          | -   | 300  | ns   |
| $t_{LSOP}$   | data bit width distortion after SOP                      | see Figure 19  | [3] -60    | -   | +60  | ns   |
| $t_{LEOPD}$  | hub EOP delay relative to $t_{HDD}$                      | see Figure 20  | [3] 0      | -   | 200  | ns   |
| $t_{LHESK}$  | hub EOP output width skew                                | see Figure 20  | [3] -300   | -   | +300 | ns   |

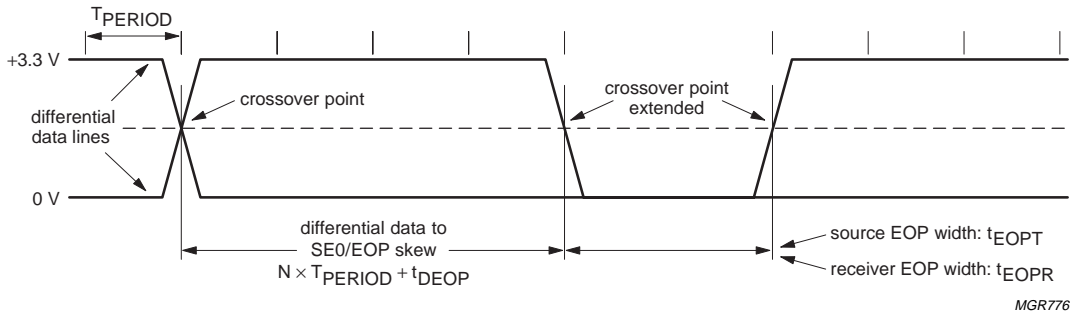
- [1] Test circuit: see Figure 22.
- [2] Excluding the first transition from Idle state.
- [3] Characterized only, not tested. Limits guaranteed by design.





$T_{PERIOD}$  is the bit duration corresponding with the USB data rate.

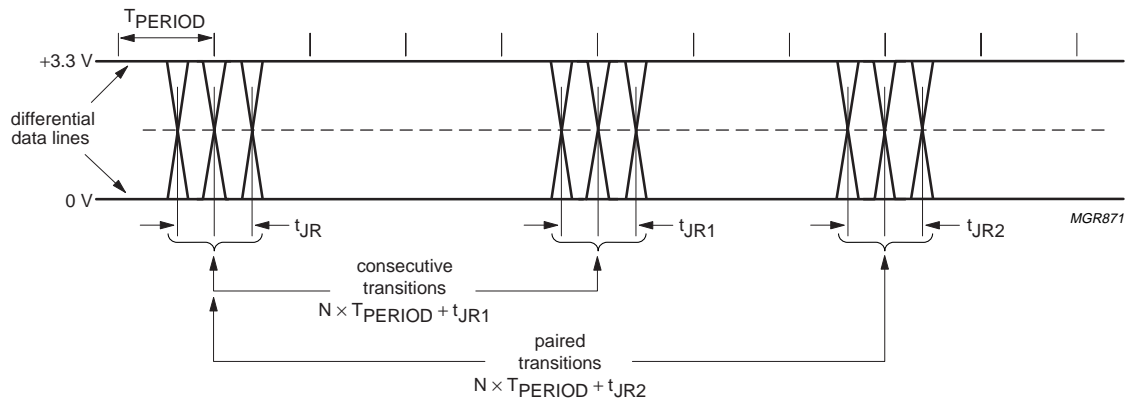
**Fig 15. Source differential data jitter.**



$T_{PERIOD}$  is the bit duration corresponding with the USB data rate.

Full-speed timing symbols have a subscript prefix 'F', low-speed timings a prefix 'L'.

**Fig 16. Source differential data-to-EOP transition skew and EOP width.**



$T_{PERIOD}$  is the bit duration corresponding with the USB data rate.

**Fig 17. Receiver differential data jitter.**

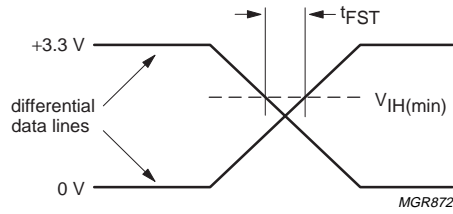
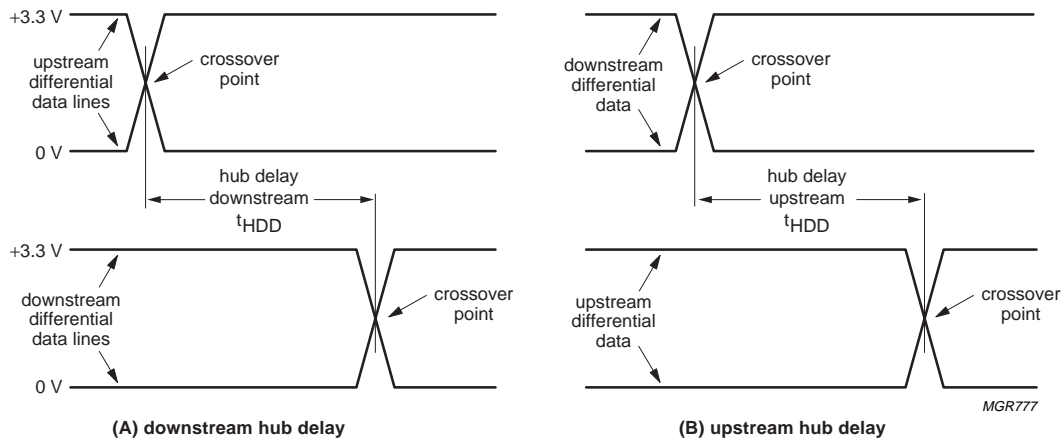


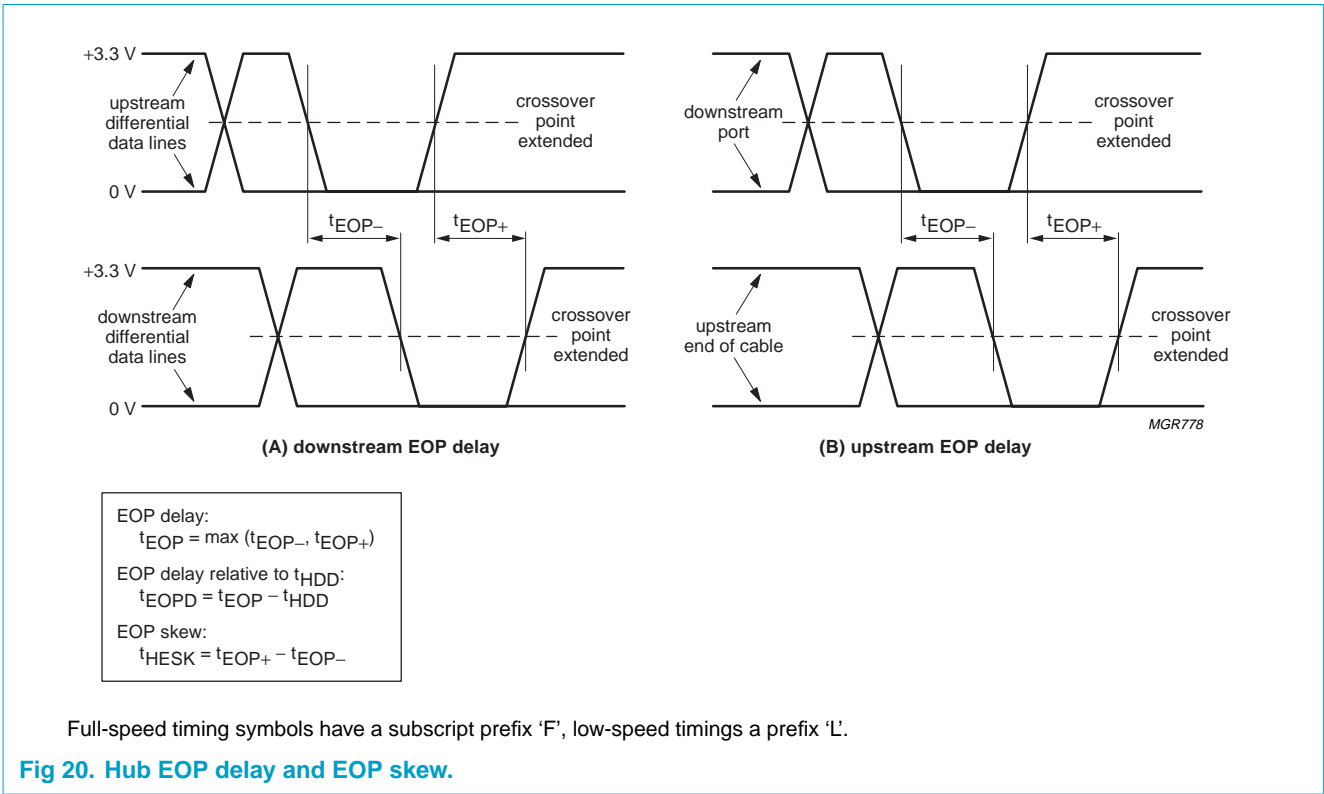
Fig 18. Receiver SE0 width tolerance.



SOP distortion:  
 $t_{SOP} = t_{HDD}(\text{next J}) - t_{HDD}(\text{SOP})$

Full-speed timing symbols have a subscript prefix 'F', low-speed timings a prefix 'L'.

Fig 19. Hub differential data delay and SOP distortion.



**Table 34: Dynamic characteristics: I<sup>2</sup>C-bus pins (SDA, SCL)**

$V_{CC}$  and  $T_{amb}$  within recommended operating range;  $V_{DD} = +5\text{ V}$ ;  $V_{SS} = V_{GND}$ ;  $V_{IL}$  and  $V_{IH}$  between  $V_{SS}$  and  $V_{DD}$ .

| Symbol       | Parameter                         | Conditions                | Min              | Typ                  | Max  | Unit          |
|--------------|-----------------------------------|---------------------------|------------------|----------------------|------|---------------|
| $f_{SCL}$    | SCL clock frequency               | $f_{XTAL} = 6\text{ MHz}$ | 0                | 93.75 <sup>[1]</sup> | 100  | kHz           |
| $t_{BUF}$    | bus free time                     |                           | 4.7              | -                    | -    | $\mu\text{s}$ |
| $t_{SU;STA}$ | START condition set-up time       |                           | 250              | -                    | -    | ns            |
| $t_{HD;STA}$ | hold time START condition         |                           | 4.0              | -                    | -    | $\mu\text{s}$ |
| $t_{LOW}$    | SCL LOW time                      |                           | 4.7              | -                    | -    | $\mu\text{s}$ |
| $t_{HIGH}$   | SCL HIGH time                     |                           | 4.0              | -                    | -    | $\mu\text{s}$ |
| $t_r$        | SCL and SDA rise time             |                           | <sup>[2]</sup> - | -                    | 1000 | ns            |
| $t_f$        | SCL and SDA fall time             |                           | -                | -                    | 300  | ns            |
| $t_{SU;DAT}$ | data set-up time                  |                           | 250              | -                    | -    | ns            |
| $t_{HD;DAT}$ | data hold time                    |                           | 0                | -                    | -    | $\mu\text{s}$ |
| $t_{VD;DAT}$ | SCL LOW to data out valid time    |                           | -                | -                    | 0.4  | $\mu\text{s}$ |
| $t_{SU;STO}$ | STOP condition set-up time        |                           | 4.0              | -                    | -    | $\mu\text{s}$ |
| $C_b$        | capacitive load for each bus line |                           | -                | -                    | 400  | pF            |

[1]  $f_{SCL} = 1/64 f_{XTAL}$ .

[2] Rise time is determined by  $C_b$  and pull-up resistor value  $R_p$  (typ. 4.7 k $\Omega$ ).

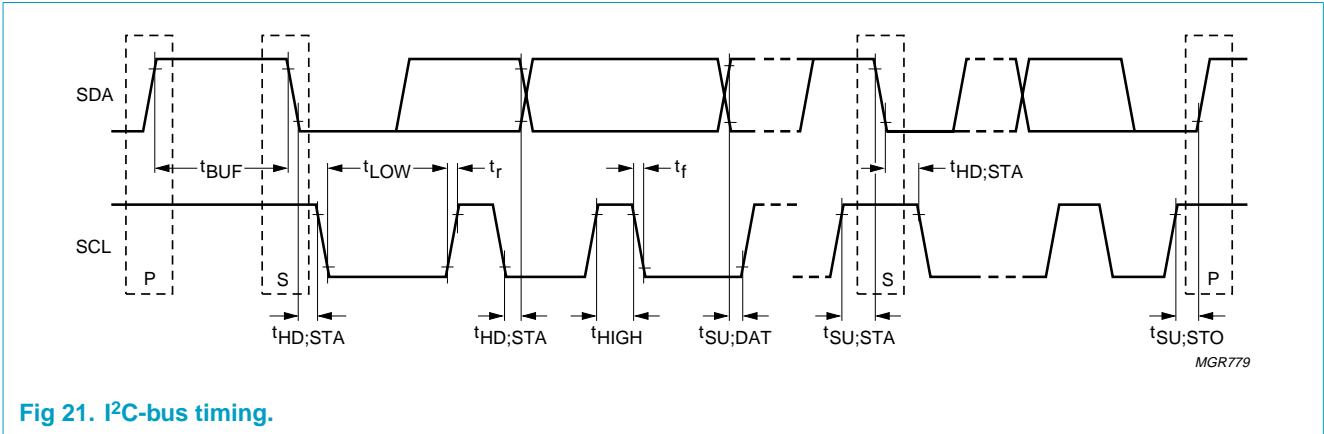
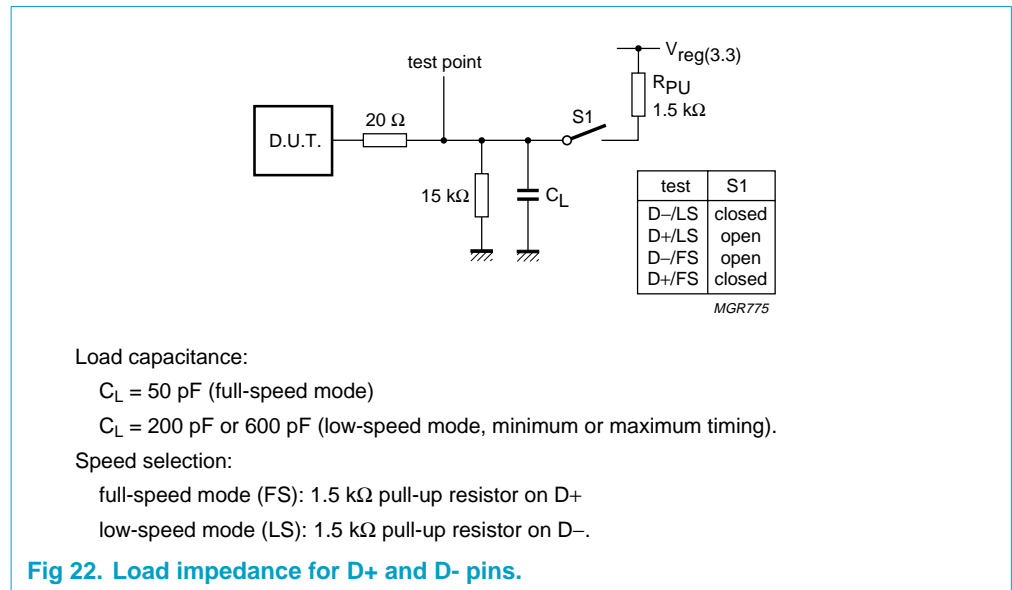


Fig 21. I<sup>2</sup>C-bus timing.

### 16. Test information

The dynamic characteristics of the analog I/O ports (D+ and D-) as listed in Table 32 and Table 33, were determined using the circuit shown in Figure 22.



Load capacitance:

$C_L = 50 \text{ pF}$  (full-speed mode)

$C_L = 200 \text{ pF}$  or  $600 \text{ pF}$  (low-speed mode, minimum or maximum timing).

Speed selection:

full-speed mode (FS):  $1.5 \text{ k}\Omega$  pull-up resistor on D+

low-speed mode (LS):  $1.5 \text{ k}\Omega$  pull-up resistor on D-.

Fig 22. Load impedance for D+ and D- pins.

17. Package outline

SO32: plastic small outline package; 32 leads; body width 7.5 mm

SOT287-1

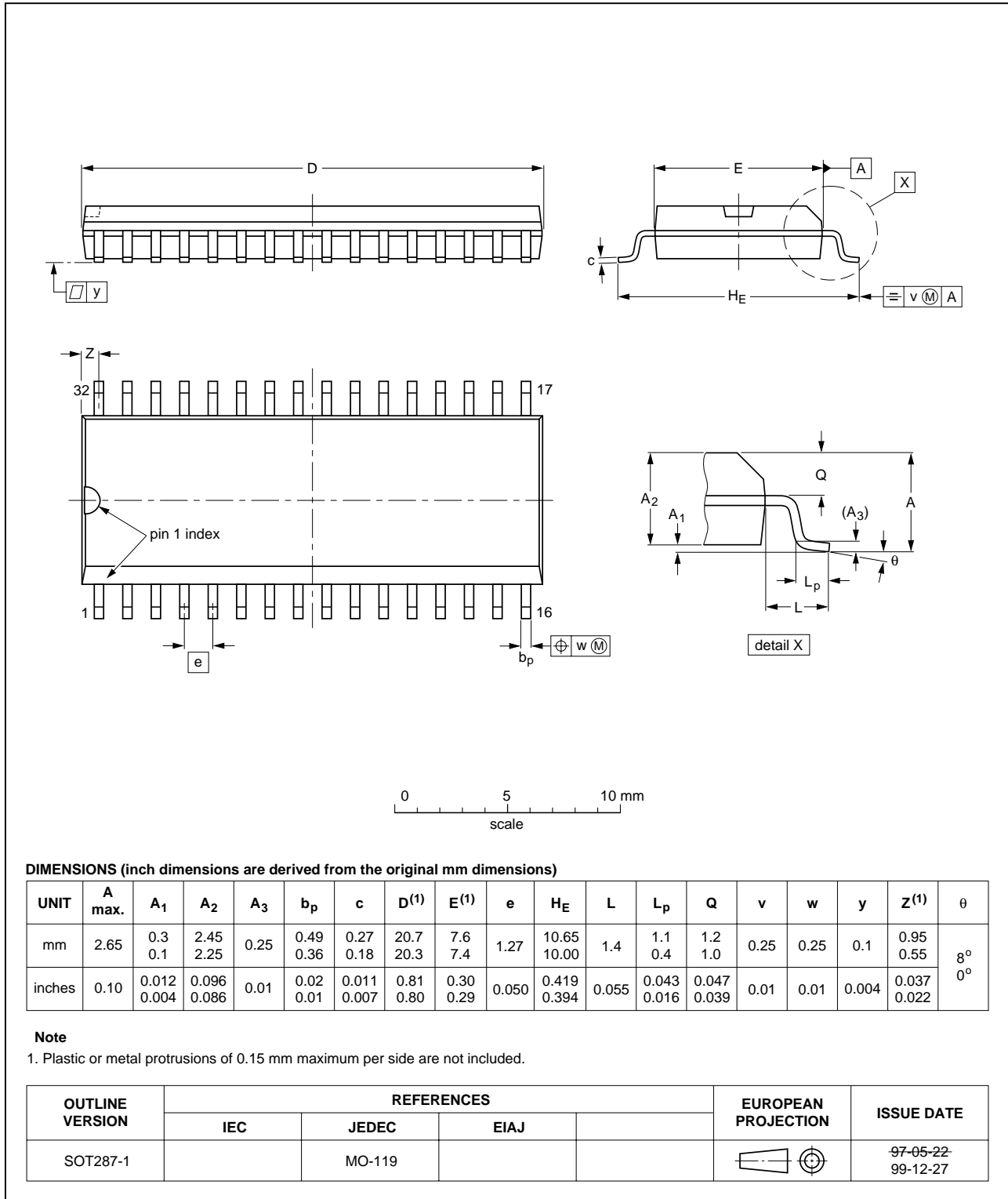


Fig 23. SO32 package outline.

SDIP32: plastic shrink dual in-line package; 32 leads (400 mil)

SOT232-1

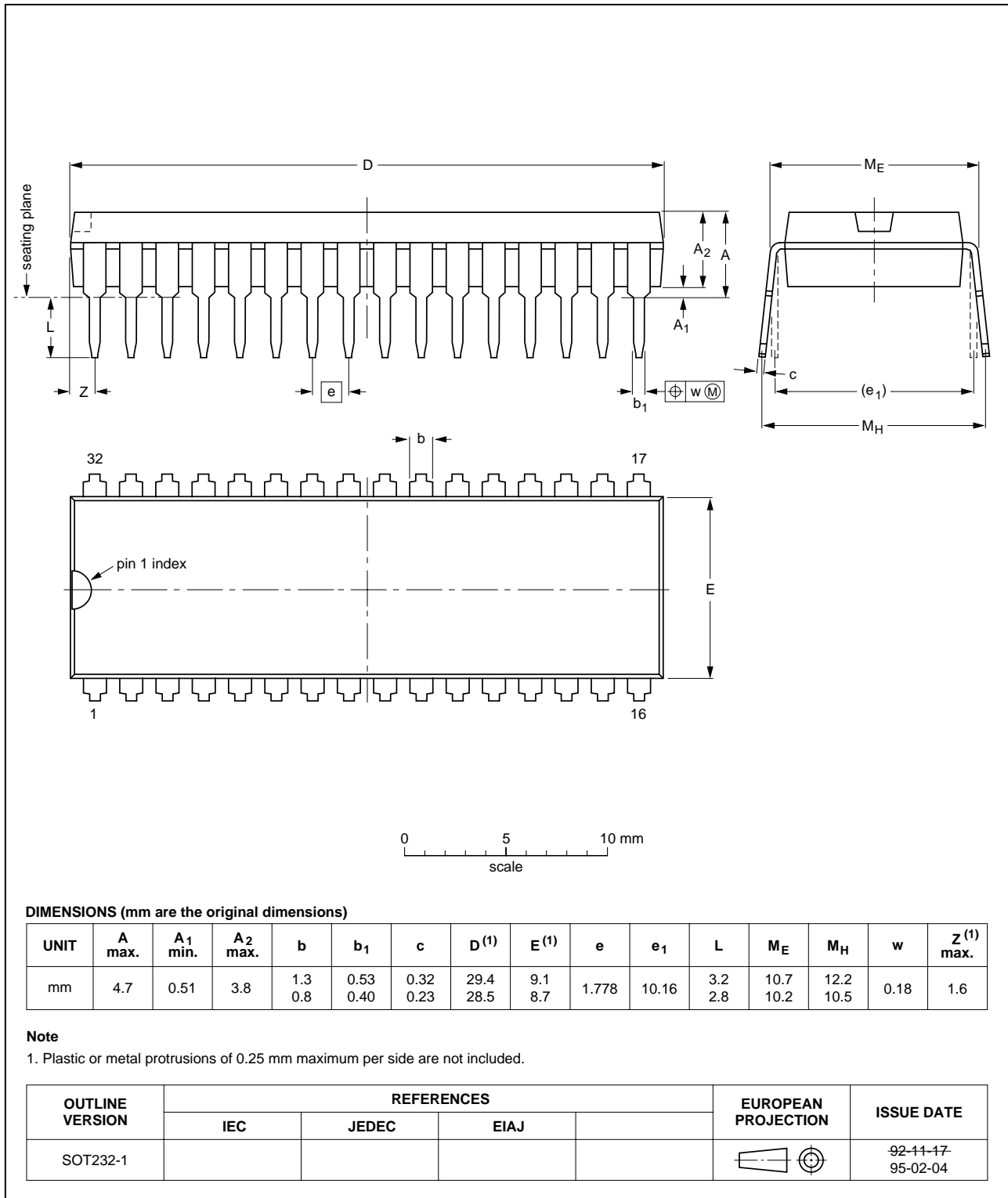


Fig 24. SDIP32 package outline.



LQFP32: plastic low profile quad flat package; 32 leads; body 7 x 7 x 1.4 mm

SOT358-1

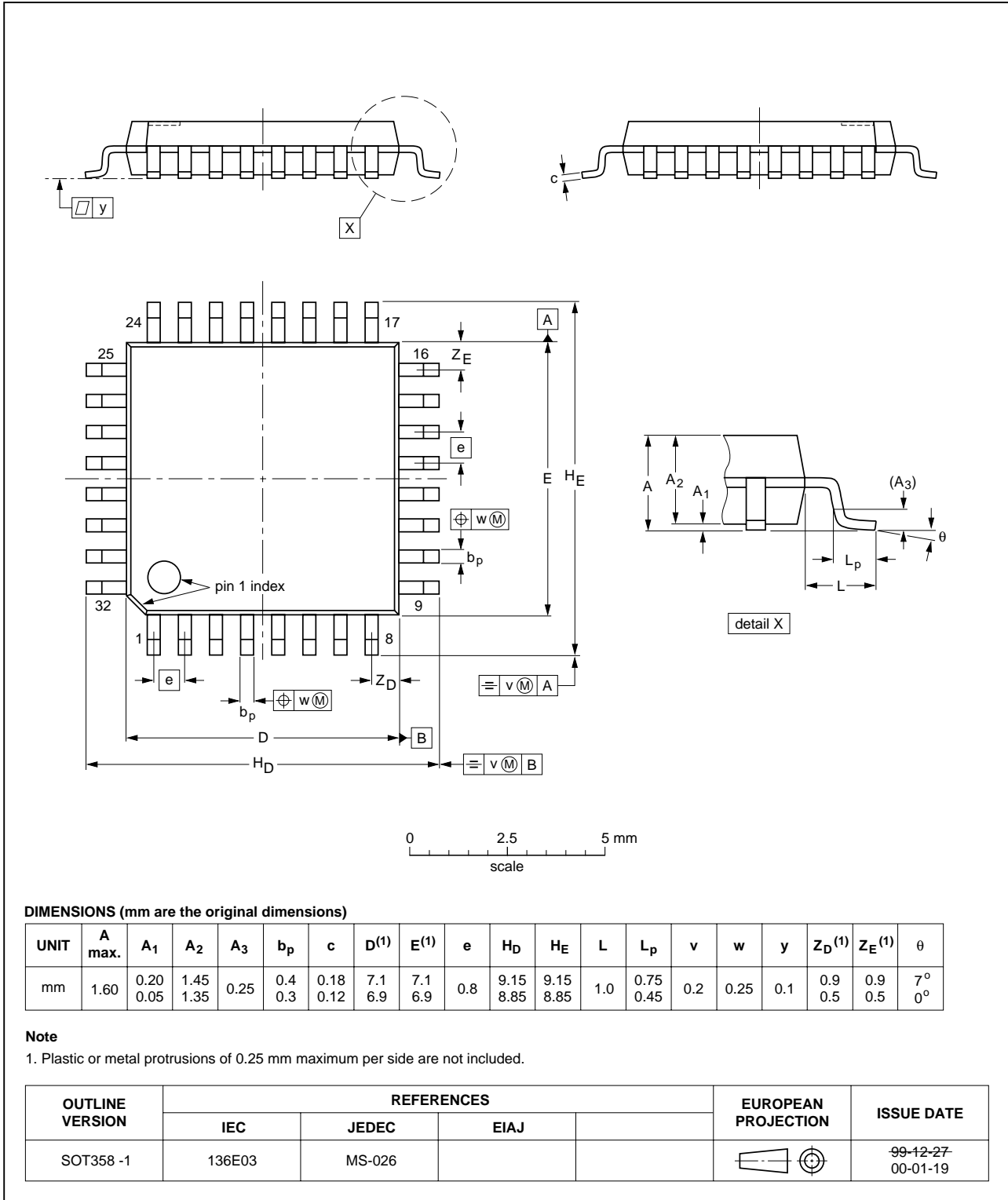


Fig 25. LQFP32 package outline.

## 18. Soldering

### 18.1 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.

### 18.2 Surface mount packages

#### 18.2.1 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 preferably be kept below 230 °C.

#### 18.2.2 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.

### 18.2.3 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.

## 18.3 Through-hole mount packages

### 18.3.1 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.

### 18.3.2 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.

### 18.4 Package related soldering information

Table 35: Suitability of IC packages for wave, reflow and dipping soldering methods

| Mounting           | Package                                      | Soldering method                  |                       |          |
|--------------------|--|-----------------------------------|-----------------------|----------|
|                    |  | Wave                              | Reflow <sup>[1]</sup> | Dipping  |
| Through-hole mount | DBS, DIP, HDIP, SDIP, SIL                    | suitable <sup>[2]</sup>           | –                     | suitable |
| Surface mount      | BGA, LFBGA, SQFP, TFBGA                      | not suitable                      | suitable              | –        |
|                    | HBCC, HLQFP, HSQFP, HSOP, HTQFP, HTSSOP, SMS | not suitable <sup>[3]</sup>       | suitable              | –        |
|                    | PLCC <sup>[4]</sup> , SO, SOJ                | suitable                          | suitable              | –        |
|                    | LQFP, QFP, TQFP                              | not recommended <sup>[4][5]</sup> | suitable              | –        |
|                    | SSOP, TSSOP, VSO                             | not recommended <sup>[6]</sup>    | suitable              | –        |

- [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.

## 19. Revision history

Table 36: Revision history

| Rev | Date     | CPCN | Description  |
|-----|----------|------|--|
| 03  | 20000329 |      | <p><b>Product specification, third version; supersedes ISP1122-02 of 4 October 1999 (9397 750 06389). Modifications:</b></p> <ul style="list-style-type: none"> <li>• <b>Table 1 “Ordering information”:</b> table note on LQFP32 availability removed</li> <li>• <b>Table 23 “Configuration bits”:</b> values of bits C7 and C6 exchanged</li> <li>• <b>Section 12.4 “Reference circuits”:</b> resistor value for soft turn-on RC-circuit changed from 10 kΩ to 47 kΩ; see also <b>Figure 10 to 13.</b></li> </ul>  |
| 02  | 19991004 |      | <p><b>Product specification, second version; supersedes initial version ISP1122-01 of 3 June 1999 (9397 750 05154). Modifications:</b></p> <ul style="list-style-type: none"> <li>• Terminology made consistent: ganged power switching, global overcurrent detection</li> <li>• Added note on availability of LQFP32 to <b>Table 1 “Ordering information”</b></li> <li>• Updated reference circuits in <b>Section 12.4 “Reference circuits”:</b> pull-up resistors changed to 330 kΩ, soft turn-on RC network: capacitor moved and changed to 0.1 μF</li> <li>• Updated <b>Figure 22 “Load impedance for D+ and D- pins.”:</b> <math>V_{CC} \rightarrow V_{reg(3.3)}</math>.</li> </ul> |
| 01  | 19990603 |      | <b>Product specification; initial version.</b>   |

## 20. Data sheet status

| Datasheet status          | Product status | Definition <sup>[1]</sup>  |
|---------------------------|----------------|--|
| Objective specification   | Development    | This data sheet contains the design target or goal specifications for product development. Specification may change in any manner without notice.  |
| Preliminary specification | Qualification  | This data sheet contains preliminary data, and supplementary data will be published at a later date. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product. |
| Product specification     | Production     | This data sheet contains final specifications. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.   |

[1] Please consult the most recently issued data sheet before initiating or completing a design.

## 21. 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.

**Application information** — Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

## 22. Disclaimers

**Life support** — 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 Semiconductors

## 24. Trademarks

**ACPI** — is an open industry specification for PC power management, co-developed by Intel Corp., Microsoft Corp. and Toshiba

**GoodLink** — is a trademark of Royal Philips Electronics

**OnNow** — is a trademark of Microsoft Corp.

customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips Semiconductors for any damages resulting from such application.

**Right to make changes** — Philips Semiconductors reserves the right to make changes, without notice, in the products, including circuits, standard cells, and/or software, described or contained herein in order to improve design and/or performance. Philips Semiconductors assumes no responsibility or liability for the use of any of these products, conveys no licence or title under any patent, copyright, or mask work right to these products, and makes no representations or warranties that these products are free from patent, copyright, or mask work right infringement, unless otherwise specified.

## 23. Licenses

### Purchase of Philips I<sup>2</sup>C components



Purchase of Philips I<sup>2</sup>C components conveys a license under the Philips' I<sup>2</sup>C patent to use the components in the I<sup>2</sup>C system provided the system conforms to the I<sup>2</sup>C 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:** Tel. +61 2 9704 8141, Fax. +61 2 9704 8139

**Austria:** Tel. +43 160 101, Fax. +43 160 101 1210

**Belarus:** Tel. +375 17 220 0733, Fax. +375 17 220 0773

**Belgium:** see The Netherlands

**Brazil:** see South America

**Bulgaria:** Tel. +359 268 9211, Fax. +359 268 9102

**Canada:** Tel. +1 800 234 7381

**China/Hong Kong:** Tel. +852 2 319 7888, Fax. +852 2 319 7700

**Colombia:** see South America

**Czech Republic:** see Austria

**Denmark:** Tel. +45 3 288 2636, Fax. +45 3 157 0044

**Finland:** Tel. +358 961 5800, Fax. +358 96 158 0920

**France:** Tel. +33 14 099 6161, Fax. +33 14 099 6427

**Germany:** Tel. +49 40 23 5360, Fax. +49 402 353 6300

**Hungary:** see Austria

**India:** Tel. +91 22 493 8541, Fax. +91 22 493 8722

**Indonesia:** see Singapore

**Ireland:** Tel. +353 17 64 0000, Fax. +353 17 64 0200

**Israel:** Tel. +972 36 45 0444, Fax. +972 36 49 1007

**Italy:** Tel. +39 039 203 6838, Fax. +39 039 203 6800

**Japan:** Tel. +81 33 740 5130, Fax. +81 3 3740 5057

**Korea:** Tel. +82 27 09 1412, Fax. +82 27 09 1415

**Malaysia:** Tel. +60 37 50 5214, Fax. +60 37 57 4880

**Mexico:** Tel. +9-5 800 234 7381

**Middle East:** see Italy

**For all other countries apply to:** Philips Semiconductors,  
International Marketing & Sales Communications,  
Building BE, P.O. Box 218, 5600 MD EINDHOVEN,  
The Netherlands, Fax. +31 40 272 4825

**Netherlands:** Tel. +31 40 278 2785, Fax. +31 40 278 8399

**New Zealand:** Tel. +64 98 49 4160, Fax. +64 98 49 7811

**Norway:** Tel. +47 22 74 8000, Fax. +47 22 74 8341

**Philippines:** Tel. +63 28 16 6380, Fax. +63 28 17 3474

**Poland:** Tel. +48 22 5710 000, Fax. +48 22 5710 001

**Portugal:** see Spain

**Romania:** see Italy

**Russia:** Tel. +7 095 755 6918, Fax. +7 095 755 6919

**Singapore:** Tel. +65 350 2538, Fax. +65 251 6500

**Slovakia:** see Austria

**Slovenia:** see Italy

**South Africa:** Tel. +27 11 471 5401, Fax. +27 11 471 5398

**South America:** Tel. +55 11 821 2333, Fax. +55 11 829 1849

**Spain:** Tel. +34 33 01 6312, Fax. +34 33 01 4107

**Sweden:** Tel. +46 86 32 2000, Fax. +46 86 32 2745

**Switzerland:** Tel. +41 14 88 2686, Fax. +41 14 81 7730

**Taiwan:** Tel. +886 22 134 2865, Fax. +886 22 134 2874

**Thailand:** Tel. +66 27 45 4090, Fax. +66 23 98 0793

**Turkey:** Tel. +90 216 522 1500, Fax. +90 216 522 1813

**Ukraine:** Tel. +380 44 264 2776, Fax. +380 44 268 0461

**United Kingdom:** Tel. +44 208 730 5000, Fax. +44 208 754 8421

**United States:** Tel. +1 800 234 7381

**Uruguay:** see South America

**Vietnam:** see Singapore

**Yugoslavia:** Tel. +381 11 3341 299, Fax. +381 11 3342 553

**Internet:** <http://www.semiconductors.philips.com>

(SCA69)

## Contents

|           |  |           |           |  |           |
|-----------|--|-----------|-----------|--|-----------|
| <b>1</b>  | <b>General description</b> . . . . .             | <b>1</b>  | <b>11</b> | <b>Hub power modes</b> . . . . .                 | <b>22</b> |
| <b>2</b>  | <b>Features</b> . . . . .                        | <b>1</b>  | 11.1      | Voltage drop requirements . . . . .              | 22        |
| <b>3</b>  | <b>Ordering information</b> . . . . .            | <b>2</b>  | 11.1.1    | Self-powered hubs . . . . .                      | 22        |
| <b>4</b>  | <b>Block diagram</b> . . . . .                   | <b>2</b>  | 11.1.2    | Bus-powered hubs . . . . .                       | 23        |
| <b>5</b>  | <b>Pinning information</b> . . . . .             | <b>3</b>  | <b>12</b> | <b>Overcurrent detection</b> . . . . .           | <b>24</b> |
| 5.1       | ISP1122D (SO32) and ISP1122NB (SDIP32) . . . . . | 3         | 12.1      | Overcurrent circuit description . . . . .        | 24        |
| 5.1.1     | Pinning . . . . .                                | 3         | 12.2      | Power switch selection . . . . .                 | 24        |
| 5.1.2     | Pin description . . . . .                        | 3         | 12.3      | Tuning the overcurrent trip voltage . . . . .    | 25        |
| 5.2       | ISP1122BD (LQFP32) . . . . .                     | 6         | 12.4      | Reference circuits . . . . .                     | 25        |
| 5.2.1     | Pinning . . . . .                                | 6         | <b>13</b> | <b>Limiting values</b> . . . . .                 | <b>30</b> |
| 5.2.2     | Pin description . . . . .                        | 6         | <b>14</b> | <b>Static characteristics</b> . . . . .          | <b>31</b> |
| <b>6</b>  | <b>Functional description</b> . . . . .          | <b>8</b>  | <b>15</b> | <b>Dynamic characteristics</b> . . . . .         | <b>32</b> |
| 6.1       | Analog transceivers . . . . .                    | 8         | <b>16</b> | <b>Test information</b> . . . . .                | <b>38</b> |
| 6.2       | Philips Serial Interface Engine (SIE) . . . . .  | 9         | <b>17</b> | <b>Package outline</b> . . . . .                 | <b>39</b> |
| 6.3       | Hub repeater . . . . .                           | 9         | <b>18</b> | <b>Soldering</b> . . . . .                       | <b>42</b> |
| 6.4       | End-of-frame timers . . . . .                    | 9         | 18.1      | Introduction . . . . .                           | 42        |
| 6.5       | General and individual port controller . . . . . | 9         | 18.2      | Surface mount packages . . . . .                 | 42        |
| 6.6       | GoodLink . . . . .                               | 9         | 18.2.1    | Reflow soldering . . . . .                       | 42        |
| 6.7       | Bit clock recovery . . . . .                     | 9         | 18.2.2    | Wave soldering . . . . .                         | 42        |
| 6.8       | Voltage regulator . . . . .                      | 9         | 18.2.3    | Manual soldering . . . . .                       | 43        |
| 6.9       | PLL clock multiplier . . . . .                   | 10        | 18.3      | Through-hole mount packages . . . . .            | 43        |
| 6.10      | Overcurrent detection . . . . .                  | 10        | 18.3.1    | Soldering by dipping or by solder wave . . . . . | 43        |
| 6.11      | I <sup>2</sup> C-bus interface . . . . .         | 10        | 18.3.2    | Manual soldering . . . . .                       | 43        |
| <b>7</b>  | <b>Modes of operation</b> . . . . .              | <b>10</b> | 18.4      | Package related soldering information . . . . .  | 44        |
| <b>8</b>  | <b>Endpoint descriptions</b> . . . . .           | <b>11</b> | <b>19</b> | <b>Revision history</b> . . . . .                | <b>45</b> |
| 8.1       | Hub endpoint 0 (control) . . . . .               | 11        | <b>20</b> | <b>Data sheet status</b> . . . . .               | <b>46</b> |
| 8.2       | Hub endpoint 1 (interrupt) . . . . .             | 11        | <b>21</b> | <b>Definitions</b> . . . . .                     | <b>46</b> |
| <b>9</b>  | <b>Host requests</b> . . . . .                   | <b>12</b> | <b>22</b> | <b>Disclaimers</b> . . . . .                     | <b>46</b> |
| 9.1       | Standard requests . . . . .                      | 12        | <b>23</b> | <b>Licenses</b> . . . . .                        | <b>46</b> |
| 9.2       | Hub specific requests . . . . .                  | 13        | <b>24</b> | <b>Trademarks</b> . . . . .                      | <b>46</b> |
| 9.3       | Descriptors . . . . .                            | 15        |           |  |           |
| 9.4       | Hub responses . . . . .                          | 18        |           |  |           |
| 9.4.1     | Get device status . . . . .                      | 18        |           |  |           |
| 9.4.2     | Get configuration . . . . .                      | 18        |           |  |           |
| 9.4.3     | Get interface status . . . . .                   | 18        |           |  |           |
| 9.4.4     | Get hub status . . . . .                         | 18        |           |  |           |
| 9.4.5     | Get port status . . . . .                        | 19        |           |  |           |
| 9.4.6     | Get configuration descriptor . . . . .           | 20        |           |  |           |
| 9.4.7     | Get device descriptor . . . . .                  | 20        |           |  |           |
| 9.4.8     | Get hub descriptor . . . . .                     | 20        |           |  |           |
| 9.4.9     | Get string descriptor (0) . . . . .              | 20        |           |  |           |
| 9.4.10    | Get string descriptor (1) . . . . .              | 20        |           |  |           |
| 9.4.11    | Get string descriptor (2) . . . . .              | 20        |           |  |           |
| <b>10</b> | <b>I<sup>2</sup>C-bus interface</b> . . . . .    | <b>20</b> |           |  |           |
| 10.1      | Protocol . . . . .                               | 20        |           |  |           |
| 10.2      | Hardware connections . . . . .                   | 21        |           |  |           |
| 10.3      | Data transfer . . . . .                          | 21        |           |  |           |



**PHILIPS**

*Let's make things better.*