1. General description

The PCA9601 is designed to isolate I^2C-bus capacitance, allowing long buses to be driven in point-to-point or multipoint applications of up to 4000 pF. The PCA9601 is a higher-speed version of the P82B96 and a higher drive version of the PCA9600 that allows many more Fast-mode Plus (Fm+) slaves on remote daughter cards in applications with temperature range of 0 °C to 85 °C.

It creates a non-latching, bidirectional, logic interface between a normal I^2C-bus and a range of other higher capacitance or different voltage bus configurations. It can operate at speeds up to at least 1 MHz, and the high drive side is compatible with the Fast-mode Plus specifications.

The PCA9601 features temperature-stabilized logic voltage levels at its SX/SY interface making it suitable for interfacing with buses that have non I^2C-bus-compliant logic levels such as SMBus, PMBus, or with microprocessors that use those same TTL logic levels.

15 mA drive capability over 0 °C to 85 °C at SX/SY allows driving a 5 V Fm+ bus with 470 pF loading.

The separation of the bidirectional I^2C-bus signals into unidirectional TX and RX signals enables the SDA and SCL signals to be transmitted via balanced transmission lines (twisted pairs), or with galvanic isolation using opto or magnetic coupling. The TX and RX signals may be connected together to provide a normal bidirectional signal.

2. Features and benefits

- Bidirectional data transfer of I^2C-bus signals
- 15 mA SX/SY sink capability yields 5 V Fm+ bus rise time with 470 pF loads
- Isolates capacitance allowing > 400 pF on SX/SY side and 4000 pF on TX/TY side
- 1 MHz operation on up to 20 meters of wire (see AN10658)
- Supply voltage range of 2.5 V to 15 V with I^2C-bus logic levels on SX/SY side independent of supply voltage
- Splits I^2C-bus signal into pairs of forward/reverse TX/RX, TY/RY signals for interface with opto-electrical isolators and similar devices that need unidirectional input and output signal paths
- Low power supply current
- ESD protection exceeds 3500 V HBM per JESD22-A114, and 1400 V CDM per JESD22-C101
-Latch-up testing is done to JEDEC Standard JESD78 which exceeds 100 mA
- Packages offered: SO8 and TSSOP8 (MSOP8)
3. Applications

- Interface between I²C-buses operating at different logic levels (for example, 5 V and 3 V or 15 V)
- Interface between I²C-bus and SMBus (350 μA) standard or Fm+ standard
- Simple conversion of I²C-bus SDA or SCL signals to multi-drop differential bus hardware, for example, via compatible PCA82C250
- Interfaces with opto-couplers to provide opto-isolation between I²C-bus nodes up to 1 MHz
- Long distance point-to-point or multipoint architectures

4. Ordering information

Table 1. Ordering information

<table>
<thead>
<tr>
<th>Type number</th>
<th>Topside marking</th>
<th>Package</th>
<th>Description</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCA9601D</td>
<td>PCA9601</td>
<td>SO8</td>
<td>plastic small outline package; 8 leads; body width 3.9 mm</td>
<td>SOT96-1</td>
</tr>
<tr>
<td>PCA9601DP</td>
<td>9601</td>
<td>TSSOP8</td>
<td>plastic thin shrink small outline package; 8 leads; body width 3 mm</td>
<td>SOT505-1</td>
</tr>
</tbody>
</table>

4.1 Ordering options

Table 2. Ordering options

<table>
<thead>
<tr>
<th>Type number</th>
<th>Orderable part number</th>
<th>Package</th>
<th>Packing method</th>
<th>Minimum order quantity</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCA9601D</td>
<td>PCA9601D,118</td>
<td>SO8</td>
<td>REEL 13&quot; Q1/T1 STANDARD MARK SMD</td>
<td>2500</td>
<td>Tamb = -40 °C to +85 °C</td>
</tr>
<tr>
<td>PCA9601DP</td>
<td>PCA9601DP,118</td>
<td>TSSOP8</td>
<td>REEL 13&quot; Q1/T1 STANDARD MARK SMD</td>
<td>2500</td>
<td>Tamb = -40 °C to +85 °C</td>
</tr>
</tbody>
</table>
5. Block diagram

![Block diagram of PCA9601](image1)

6. Pinning information

6.1 Pinning

![Pin configuration for SO8](image2)

![Pin configuration for TSSOP8 (MSOP8)](image3)

6.2 Pin description

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SX</td>
<td>1</td>
<td>I^2^C-bus (SDA or SCL)</td>
</tr>
<tr>
<td>RX</td>
<td>2</td>
<td>receive signal</td>
</tr>
<tr>
<td>TX</td>
<td>3</td>
<td>transmit signal</td>
</tr>
<tr>
<td>GND</td>
<td>4</td>
<td>negative supply voltage</td>
</tr>
<tr>
<td>TY</td>
<td>5</td>
<td>transmit signal</td>
</tr>
<tr>
<td>RY</td>
<td>6</td>
<td>receive signal</td>
</tr>
<tr>
<td>SY</td>
<td>7</td>
<td>I^2^C-bus (SDA or SCL)</td>
</tr>
<tr>
<td>VCC</td>
<td>8</td>
<td>positive supply voltage</td>
</tr>
</tbody>
</table>
7. Functional description

Refer to Figure 1 "Block diagram of PCA9601".

The PCA9601 has two identical buffers allowing buffering of SDA and SCL I²C-bus signals. Each buffer is made up of two logic signal paths, a forward path from the I²C-bus interface, pins SX and SY which drive the buffered bus, and a reverse signal path from the buffered bus input, pins RX and RY to drive the I²C-bus interface. These paths:

- sense the voltage state of I²C-bus pins SX (and SY) and transmit this state to pin TX (and TY respectively),
- sense the state of pins RX and RY and pull the I²C-bus pin LOW whenever pin RX or pin RY is LOW.

The rest of this discussion will address only the ‘X’ side of the buffer; the ‘Y’ side is identical.

7.1 Static level offset card side

The I²C-bus pin SX is specified to allow interfacing with Fast-mode, Fm+ and TTL-based systems.

The logic threshold voltage levels at SX on this I²C-bus are independent of the IC supply voltage VCC. The maximum I²C-bus supply voltage is 15 V.

7.1.1 Fast-mode operation

When interfacing with Fast-mode systems, the SX pin is guaranteed to sink the normal 3 mA with a VOL of 0.74 V maximum. That guarantees compliance with the Fast-mode I²C-bus specification for all I²C-bus voltages greater than 3 V, as well as compliance with SMBus or other systems that use TTL switching levels.

SX is guaranteed to sink an external 3 mA in addition to its internally sourced pull-up of typically 300 μA (maximum 1 mA at –40 °C). When selecting the pull-up for the bus at SX, the sink capability of other connected drivers should be taken into account. Most TTL devices are specified to sink at least 4 mA so then the pull-up is limited to 3 mA by the requirement to ensure the 0.8 V TTL LOW.

For Fast-mode I²C-bus operation, the other connected I²C-bus parts may have the minimum sink capability of 3 mA. SX sources typically 300 μA (maximum 1 mA at –40 °C), which forms part of the external driver loading. When selecting the pull-up it is necessary to subtract the SX pin pull-up current, so, worst-case at –40 °C, the allowed pull-up can be limited (by external drivers) to 2 mA.

7.1.2 Fast-mode Plus operation

When the interface at SX is an Fm+ bus with a voltage greater than 4 V, its higher specified sink capability may be used. PCA9601 has a guaranteed sink capability of 15 mA at VOL = 1 V maximum over 0 °C to 85 °C. That 1 V complies with the bus LOW requirement (0.25Vbus) of any Fm+ bus operating at 4 V or greater. Since the other connected Fm+ devices have a drive capability greater than 20 mA, the pull-up may be selected for 15 mA sink current at VOL = 1 V. For a nominal 5 V bus (5.5 V maximum) the allowed pull-up is (5.5 V – 1 V) / 15 mA = 300 Ω. With 300 Ω pull-up, the Fm+ rise time of 120 ns maximum can be met with total bus loading up to 470 pF.
7.2 High drive, long distance side

The logic level on RX is determined from the power supply voltage $V_{CC}$ of the chip. Logic LOW is below 40% of $V_{CC}$, and logic HIGH is above 55% of $V_{CC}$ (with a typical switching threshold just slightly below half $V_{CC}$).

TX is an open-collector output without ESD protection diodes to $V_{CC}$. It may be connected via a pull-up resistor to a supply voltage in excess of $V_{CC}$, as long as the 15 V rating is not exceeded. It has a larger current sinking capability than a normal I2C-bus device, being able to sink a static current of greater than 30 mA, and typical 100 mA dynamic pull-down capability as well.

A logic LOW is transmitted to TX when the voltage at I2C-bus pin SX is below 0.425 V. A logic LOW at RX will cause I2C-bus pin SX to be pulled to a logic LOW level in accordance with I2C-bus requirements (maximum 1.5 V in 5 V applications) but not low enough to be looped back to the TX output and cause the buffer to latch LOW.

The LOW level this chip can achieve on the I2C-bus by a LOW at RX is typically 0.64 V when sinking 1 mA.

If the supply voltage $V_{CC}$ fails, then neither the I2C-bus nor the TX output will be held LOW. Their open-collector configuration allows them to be pulled up to the rated maximum of 15 V even without $V_{CC}$ present. The input configuration on SX and RX also presents no loading of external signals when $V_{CC}$ is not present.

The effective input capacitance of any signal pin, measured by its effect on bus rise times, is less than 10 pF for all bus voltages and supply voltages including $V_{CC} = 0$ V.

7.3 Connections to other bus buffers

Two or more SX or SY I/Os must not be interconnected. The PCA9601 design does not support this configuration. Bidirectional I2C-bus signals do not allow any direction control pin so, instead, slightly different logic LOW voltage levels are used at SX/SY to avoid latching of this buffer. A ‘regular I2C-bus LOW’ applied at the RX/RY of a PCA9601 will be propagated to SX/SY as a ‘buffered LOW’ with a slightly higher voltage level. If this special ‘buffered LOW’ is applied to the SX/SY of another PCA9601, that second PCA9601 will not recognize it as a ‘regular I2C-bus LOW’ and will not propagate it to its TX/TY output.

The SX/SY side of PCA9601 may not be connected to similar buffers that rely on special logic thresholds for their operation, for example P82B96, PCA9511A, PCA9515A, ‘B’ side of PCA9517, etc. The SX/SY side is only intended for, and compatible with, the normal I2C-bus logic voltage levels of I2C-bus master and slave chips, or even TX/RX signals of a second PCA9601 or P82B96 if required. The TX/RX and TY/RY I/O pins use the standard I2C-bus logic voltage levels of all I2C-bus parts. There are no restrictions on the interconnection of the TX/RX and TY/RY I/O pins to other PCA9601s, for example in a star or multipoint configuration with the TX/RX and TY/RY I/O pins on the common bus and the SX/SY side connected to the line card slave devices. For more details see Application Note AN10658, “Sending I2C-bus signals via long communication cables”.
### 7.4 Comparison of PCA9601/PCA9600 and P82B96

The PCA9601 is a direct upgrade of the P82B96 with the significant differences summarized in Table 4. The PCA9601 provides improved interface to the higher drive Fast-mode Plus devices on the SX/SY sides.

**Table 4. PCA9601/PCA9600 versus P82B96**

<table>
<thead>
<tr>
<th>Detail</th>
<th>PCA9601/PCA9600</th>
<th>P82B96</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage (VCC) range:</td>
<td>2.5 V to 15 V</td>
<td>2 V to 15 V</td>
</tr>
<tr>
<td>Maximum operating bus voltage (independent of VCC):</td>
<td>15 V</td>
<td>15 V</td>
</tr>
<tr>
<td>Typical operating supply current:</td>
<td>5 mA</td>
<td>1 mA</td>
</tr>
<tr>
<td>Typical LOW-LEVEL input voltage on I2C-bus (SX/SY side):</td>
<td>0.5 V over −40 °C to +85 °C</td>
<td>0.65 V at 25 °C</td>
</tr>
<tr>
<td>LOW-level output voltage on I2C-bus (SX/SY side; 3 mA sink):</td>
<td>0.74 V (max.) over −40 °C to +85 °C</td>
<td>0.88 V (typ.) at 25 °C</td>
</tr>
<tr>
<td>LOW-level output voltage on I2C-bus (SX/SY side; 15 mA sink):</td>
<td>1 V (max.) over 0 °C to 85 °C (PCA9601 only)</td>
<td>n/a</td>
</tr>
<tr>
<td>Temperature coefficient of VIL / VOL:</td>
<td>0 mV/°C</td>
<td>−2 mV/°C</td>
</tr>
<tr>
<td>Logic voltage levels on SX/SY bus (independent of VCC):</td>
<td>compatible with I²C-bus and similar buses using TTL levels (SMBus, etc.)</td>
<td>compatible with I²C-bus and similar buses using TTL levels (SMBus, etc.)</td>
</tr>
<tr>
<td>Typical propagation delays:</td>
<td>&lt; 100 ns</td>
<td>&lt; 200 ns</td>
</tr>
<tr>
<td>TX/RX switching specifications (I²C-bus compliant):</td>
<td>yes, all classes including 1 MHz Fm+</td>
<td>yes, all classes including Fm+</td>
</tr>
<tr>
<td>RX logic levels with tighter control than I²C-bus limit of 30 % to 70 %:</td>
<td>yes, 40 % to 55 % (48 % nominal)</td>
<td>yes, 42 % to 58 % (50 % nominal)</td>
</tr>
<tr>
<td>Maximum bus speed:</td>
<td>&gt; 1 MHz</td>
<td>&gt; 400 kHz</td>
</tr>
<tr>
<td>ESD rating HBM per JESD22-A114:</td>
<td>&gt; 3500 V</td>
<td>&gt; 3500 V</td>
</tr>
<tr>
<td>Package:</td>
<td>SO8, TSSOP8 (MSOP8)</td>
<td>SO8, TSSOP8 (MSOP8)</td>
</tr>
</tbody>
</table>

When the device driving the PCA9601/PCA9600 is an I²C-bus compatible device, then the PCA9601 is an improvement on the P82B96 as shown in Table 4. There will always be exceptions however, and if the device driving the bus buffer is not I²C-bus compatible (e.g., you need to use the micro already in the system and bit-bang using two GPIO pins) then here are some considerations that would point to using the P82B96 instead:

- **When the pull-up must be the weakest one possible.** The spec is 200 µA for P82B96, but it typically works even below that. And if designing for a temperature range −40 °C up to +60 °C, then the driver when sinking 200 µA only needs to drive a guaranteed low of 0.55 V. For the PCA9601/PCA9600, over that same temperature range and when sinking 1.3 mA (at −40 °C), the device driving the bus buffer must provide the required low of 0.425 V.

- **When the lower operating temperature range is restricted (say 0 °C).** The P82B96 larger SX voltage levels then make a better typical match with the driver, even when the supply is as low as 3.3 V. For an I²C-bus compliant driver on 3.3 V the P82B96 is required to guarantee a bus low that is below 0.83 V. P82B96 guarantees that with a 200 µA pull-up.
• When the operating temperature range is restricted at both limits. An I2C driver's typical output is well below 0.4 V and the P82B96 typically requires 0.6 V input even at +60 °C, so there is a reasonable margin. The PCA9601/PCA9600 requires a typical input low of 0.5 V so its typical margin is smaller. At 0 °C the driver requires a typical input low of 1.16 V and P82B96 provides 0.75 V, so again the typical margin is already quite big and even though PCA9601/PCA9600 is better, providing 0.7 V, that difference is not big.

8. Limiting values

Table 5. Limiting values
In accordance with the Absolute Maximum Rating System (IEC 60134).
Voltages with respect to pin GND.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{CC}</td>
<td>supply voltage</td>
<td>V_{CC} to GND</td>
<td>-0.3</td>
<td>+18</td>
<td>V</td>
</tr>
<tr>
<td>V_{I2C-bus}</td>
<td>I2C-bus voltage</td>
<td>SX and SY; I2C-bus SDA or SCL</td>
<td>-0.3</td>
<td>+18</td>
<td>V</td>
</tr>
<tr>
<td>V_O</td>
<td>output voltage</td>
<td>TX and TY; buffered output</td>
<td>[1]</td>
<td>-0.3</td>
<td>+18</td>
</tr>
<tr>
<td>V_I</td>
<td>input voltage</td>
<td>RX and RY; receive input</td>
<td>[1]</td>
<td>-0.3</td>
<td>+18</td>
</tr>
<tr>
<td>I_{I2C-bus}</td>
<td>I2C-bus current</td>
<td>SX and SY; I2C-bus SDA or SCL</td>
<td>-</td>
<td>250</td>
<td>mA</td>
</tr>
<tr>
<td>P_{tot}</td>
<td>total power dissipation</td>
<td></td>
<td>-</td>
<td>300</td>
<td>mW</td>
</tr>
<tr>
<td>T_J</td>
<td>junction temperature</td>
<td>operating range</td>
<td>-40</td>
<td>+125</td>
<td>°C</td>
</tr>
<tr>
<td>T_{stg}</td>
<td>storage temperature</td>
<td></td>
<td>-55</td>
<td>+125</td>
<td>°C</td>
</tr>
<tr>
<td>T_{amb}</td>
<td>ambient temperature</td>
<td>operating</td>
<td>-40</td>
<td>+85</td>
<td>°C</td>
</tr>
</tbody>
</table>

[1] See also Section 10.2 “Negative undershoot below absolute minimum value”.

## 9. Characteristics

### Table 6. Characteristics

$T_{\text{amb}} = -40 \, ^{\circ}\text{C} \text{ to } +85 \, ^{\circ}\text{C}$ unless otherwise specified; voltages are specified with respect to GND with $V_{\text{CC}} = 2.5 \, \text{V} \text{ to } 15 \, \text{V}$ unless otherwise specified. Typical values are measured at $V_{\text{CC}} = 5 \, \text{V}$ and $T_{\text{amb}} = 25 \, ^{\circ}\text{C}$.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{CC}}$</td>
<td>supply voltage</td>
<td>operating</td>
<td>2.5</td>
<td>-</td>
<td>15</td>
<td>V</td>
</tr>
<tr>
<td>$I_{\text{CC}}$</td>
<td>supply current</td>
<td>$V_{\text{CC}} = 5 , \text{V}; \text{buses HIGH}$</td>
<td>-</td>
<td>5.2</td>
<td>6.75</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{\text{CC}} = 15 , \text{V}; \text{buses HIGH}$</td>
<td>-</td>
<td>5.5</td>
<td>7.3</td>
<td>mA</td>
</tr>
<tr>
<td>$\Delta I_{\text{CC}}$</td>
<td>additional supply current</td>
<td>per TX/TY output driven LOW; $V_{\text{CC}} = 5.5 , \text{V}$</td>
<td>-</td>
<td>1.4</td>
<td>3.0</td>
<td>mA</td>
</tr>
</tbody>
</table>

### Bus pull-up (load) voltages and currents

#### Pins SX and SY, I^2C-bus

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{I}}$</td>
<td>input voltage</td>
<td>open-collector; RX and RY HIGH</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>V</td>
</tr>
<tr>
<td>$V_{\text{O}}$</td>
<td>output voltage</td>
<td>open-collector; RX and RY HIGH</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>V</td>
</tr>
<tr>
<td>$I_{\text{O}}$</td>
<td>output current</td>
<td>static; $V_{\text{SX}} = V_{\text{SY}} = 0.4 , \text{V}$</td>
<td>0.3</td>
<td>-</td>
<td>15</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{\text{O(sink)}}$</td>
<td>output sink current</td>
<td>$V_{\text{SX}} = V_{\text{SY}} = 1 , \text{V}; \text{RX and RY LOW}; T_{\text{amb}} = 0 , ^{\circ}\text{C} \text{ to } 85 , ^{\circ}\text{C}$</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{\text{L}}$</td>
<td>leakage current</td>
<td>$V_{\text{SX}} = V_{\text{SY}} = 15 , \text{V}; \text{RX and RY HIGH}$</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>$\mu\text{A}$</td>
</tr>
</tbody>
</table>

#### Pins TX and TY

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{O}}$</td>
<td>output voltage</td>
<td>open-collector</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>V</td>
</tr>
<tr>
<td>$I_{\text{load}}$</td>
<td>load current</td>
<td>maximum recommended on buffered bus; $V_{\text{TX}} = V_{\text{TY}} = 0.4 , \text{V}$; SX and SY LOW on I^2C-bus = 0.4 V</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{\text{O}}$</td>
<td>output current</td>
<td>from buffered bus; $V_{\text{TX}} = V_{\text{TY}} = 1 , \text{V}$; SX and SY LOW on I^2C-bus = 0.4 V</td>
<td>60</td>
<td>130</td>
<td>-</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{\text{L}}$</td>
<td>leakage current</td>
<td>on buffered bus; $V_{\text{TX}} = V_{\text{TY}} = V_{\text{CC}} = 15 , \text{V}$; SX and SY HIGH</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>$\mu\text{A}$</td>
</tr>
</tbody>
</table>

### Input currents

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{\text{I}}$</td>
<td>input current</td>
<td>from I^2C-bus on SX and SY</td>
<td>-</td>
<td>-</td>
<td>0.3</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{RX and RY HIGH or LOW}; \text{SX and SY LOW} \leq 1 , \text{V}$</td>
<td>11</td>
<td>-</td>
<td>30</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{RX and RY HIGH}; \text{SX and SY HIGH} &gt; 1.4 , \text{V}$</td>
<td>11</td>
<td>-</td>
<td>10</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>$I_{\text{L}}$</td>
<td>leakage current</td>
<td>on buffered bus input on RX and RY; $V_{\text{RX}} = V_{\text{RY}} = 15 , \text{V}$</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>$\mu\text{A}$</td>
</tr>
</tbody>
</table>
### Output logic LOW level

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{OL}$</td>
<td>LOW-level output voltage</td>
<td>on Standard-mode or Fast-mode I²C-bus</td>
<td>-</td>
<td>0.7</td>
<td>0.74</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{SX} = I_{SY} = 3 \text{ mA}; \text{ Figure 6}$</td>
<td>-</td>
<td>0.6</td>
<td>0.65</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{SX} = I_{SY} = 0.3 \text{ mA}; \text{ Figure 5}$</td>
<td>-</td>
<td>0.85</td>
<td>1</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{SX} = I_{SY} = 15 \text{ mA}; \text{ Figure 6}$</td>
<td>-</td>
<td>0.85</td>
<td>1</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V/\Delta T$</td>
<td>voltage variation with temperature</td>
<td>$I_{SX} = I_{SY} = 0.3 \text{ mA to 3 mA}$</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>%/K</td>
</tr>
</tbody>
</table>

### Input logic switching threshold voltages

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IL}$</td>
<td>LOW-level input voltage</td>
<td>on normal I²C-bus; Figure 7</td>
<td>-</td>
<td>425</td>
<td>-</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{IH(iH)}$</td>
<td>HIGH-level input threshold voltage</td>
<td>on normal I²C-bus; Figure 8</td>
<td>580</td>
<td>-</td>
<td>-</td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V/\Delta T$</td>
<td>voltage variation with temperature</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>%/K</td>
<td></td>
</tr>
</tbody>
</table>

### Logic level threshold difference

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta V$</td>
<td>voltage difference</td>
<td>SX and SY; SX output LOW at 0.3 mA to SX input HIGH maximum</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>mV</td>
</tr>
</tbody>
</table>

### Bus release on $V_{CC}$ failure

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$</td>
<td>supply voltage</td>
<td>SX, SY, TX and TY; voltage at which all buses are to be released at 25 °C</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V/\Delta T$</td>
<td>voltage variation with temperature</td>
<td>Figure 9</td>
<td>-</td>
<td>-4</td>
<td>-</td>
<td>%/K</td>
</tr>
</tbody>
</table>
This bus pull-up current specification is intended to assist design of the bus pull-up resistor. It is not a specification of the sink capability (see $V_{OL}$ under sub-section “Output logic LOW level”). When used on an Fm+ bus the load current is limited to 15 mA by the drive capability of PCA9601. When used in a standard I2C-bus the load current is limited by the drive capability of other devices on the bus. The maximum static sink current for a Standard/Fast-mode I2C-bus is 3 mA and PCA9601 is guaranteed to sink more than 3 mA at SX/SY when its pins are holding the bus LOW. However, when an external device pulls the SX/SY pins below 1.4 V, the PCA9601 will source a current between 0 mA and 1 mA maximum. When that other external device is driving LOW it will pull the bus connected to SX or SY down to, or below, the 0.4 V level referenced in the I2C-bus specification and in these test conditions. Then that device must be able to sink up to 1 mA coming from SX/SY plus the usual pull-up current. Therefore in Standard and Fast-mode systems the external pull-up used at SX/SY should be limited to 2 mA. The typical and maximum currents sourced by SX/SY as a function of junction temperature are shown in Figure 10, and the equivalent circuit at the SX/SY interface is shown in Figure 4.

Valid over temperature for $V_{CC} \leq 5$ V. At higher $V_{CC}$, this current may increase to maximum $-20 \mu$A at $V_{CC} = 15$ V.

The input logic threshold is independent of the supply voltage.

The minimum value requirement for pull-up current, 0.3 mA, guarantees that the minimum value for $V_{SX}$ output LOW will always exceed the maximum $V_{SX}$ input HIGH level to eliminate any possibility of latching. The specified difference is guaranteed by design within any IC. While the tolerances on absolute levels allow a small probability, the LOW from one SX output is recognized by an SX input of another PCA9601, this has no consequences for normal applications. In any design the SX pins of different ICs should never be linked because the resulting system would be very susceptible to induced noise and would not support all I2C-bus operating modes.

The fall time of $V_{TX}$ from 5 V to 2.5 V in the test is approximately 10 ns.

The fall time of $V_{SX}$ from 5 V to 2.5 V in the test is approximately 20 ns.

The rise time of $V_{TX}$ from 0 V to 2.5 V in the test is approximately 15 ns.

The rise time of $V_{SX}$ from 0.7 V to 2.5 V in the test is approximately 25 ns.

Buffer response time

$V_{CC} = 5$ V; pin TX pull-up resistor = 160 $\Omega$; pin SX pull-up resistor = 2.2 k$\Omega$; no capacitive load

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_d$</td>
<td>delay time</td>
<td>$V_{SX}$ to $V_{TX}$, $V_{SY}$ to $V_{TY}$; on falling input between $V_{SX}$ = input switching threshold, and $V_{TX}$ output falling to 50 % $V_{CC}$</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{SX}$ to $V_{TX}$, $V_{SY}$ to $V_{TY}$; on rising input between $V_{SX}$ = input switching threshold, and $V_{TX}$ output reaching 50 % $V_{CC}$</td>
<td>-</td>
<td>60</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{fr}$</td>
<td>delay time</td>
<td>$V_{RX}$ to $V_{SX}$, $V_{RY}$ to $V_{SY}$; on falling input between $V_{RX}$ = input switching threshold, and $V_{SX}$ output falling to 50 % $V_{CC}$</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{RX}$ to $V_{SX}$, $V_{RY}$ to $V_{SY}$; on rising input between $V_{RX}$ = input switching threshold, and $V_{SX}$ output reaching 50 % $V_{CC}$</td>
<td>-</td>
<td>95</td>
<td>-</td>
<td>ns</td>
</tr>
</tbody>
</table>

Input capacitance

$C_i$ input capacitance

effective input capacitance of any signal pin measured by incremental bus rise times; guaranteed by design, not production tested

-   -   10  pF

Table 6. Characteristics ...continued

$T_{amb} = -40$ °C to +85 °C unless otherwise specified; voltages are specified with respect to GND with $V_{CC} = 2.5$ V to 15 V unless otherwise specified. Typical values are measured at $V_{CC} = 5$ V and $T_{amb} = 25$ °C.
Fig 4. Equivalent circuit at SX/SY

Fig 5. $V_{OL}$ as a function of junction temperature ($I_{OL} = 0.3 \, mA$)

Fig 6. $V_{OL}$ as a function of junction temperature ($I_{OL} = 3 \, mA$)

Fig 7. $V_{IL}$ as a function of junction temperature; maximum and typical values

Fig 8. $V_{IH}$ as a function of junction temperature; minimum and typical values
Fig 9. \( V_{CC} \) bus release limit over temperature; maximum values

Fig 10. Current sourced out of SX/SY as a function of junction temperature if these pins are externally pulled to 0.4 V or lower

Fig 11. Typical SX/SY current versus LOW-level output voltage
10. Application information

Refer to application notes AN10658 and AN255 for more detailed application information.

**Fig 12.** Interfacing a standard 3 mA I2C-bus or one with TTL levels (e.g. SMBus) to higher voltage or higher current sink (e.g. Fast-mode Plus) devices

This simple example may be limited, if using lowest-cost couplers, to speeds as low as 5 kHz. Refer to application notes for schematics suitable for operation to 400 kHz or higher.

**Fig 13.** Galvanic isolation of I2C-bus nodes via opto-couplers

**Fig 14.** Long distance I2C-bus communication
For more examples of faster alternatives for driving over longer cables such as Cat5 communication cable, see AN10658. Communication at 1 MHz is possible over short cables and > 400 kHz is possible over 50 m of cable.
10.1 Calculating system delays and bus clock frequency

Effective delay of SCL at slave: \[ 120 + 17V_{CCM} + (2.5 + 4 \times 10^9 \times C_b) \times V_{CCB} + 10V_{CCS} \text{ (ns)} \].

\[ C = F; \quad V = V. \]

**Fig 16.** Falling edge of SCL at master is delayed by the buffers and bus fall times

Effective delay of SCL at master: \[ 115 + (R_m \times C_m) + (0.7 \times R_b \times C_b) \text{ (ns)} \].

\[ C = F; \quad R = \Omega. \]

**Fig 17.** Rising edge of SCL at master is delayed (clock stretch) by buffer and bus rise times
Figure 16, Figure 17, and Figure 18 show the PCA9601 used to drive extended bus wiring with relatively large capacitances linking two I2C-bus nodes. It includes simplified expressions for making the relevant timing calculations for 3.3 V or 5 V operation. Because the buffers and the wiring introduce timing delays, it may be necessary to decrease the nominal SCL frequency. In most cases the actual bus frequency will be lower than the nominal Master timing due to bit-wise stretching of the clock periods.

The delay factors involved in calculation of the allowed bus speed are:

A — The propagation delay of the master signal through the buffers and wiring to the slave. The important delay is that of the falling edge of SCL because this edge ‘requests’ the data or acknowledge from a slave. See Figure 16.

B — The effective stretching of the nominal LOW period of SCL at the master caused by the buffer and bus rise times. See Figure 17.

C — The propagation delay of the slave’s response signal through the buffers and wiring back to the master. The important delay is that of a rising edge in the SDA signal. Rising edges are always slower and are therefore delayed by a longer time than falling edges. (The rising edges are limited by the passive pull-up while falling edges are actively driven); see Figure 18.

The timing requirement in any I2C-bus system is that a slave’s data response (which is provided in response to a falling edge of SCL) must be received at the master before the end of the corresponding LOW period of SCL as appears on the bus wiring at the master. Since all slaves will, as a minimum, satisfy the worst case timing requirements of their speed class (Fast-mode, Fm+, etc.), they must provide their response, allowing for the set-up time, within the minimum allowed clock LOW period, e.g., 450 ns (max.) for Fm+ parts. In systems that introduce additional delays it may be necessary to extend the minimum clock LOW period to accommodate the ‘effective’ delay of the slave’s response. The effective delay of the slave’s response equals the total delays in SCL falling edge from the master reaching the slave (Figure 16) minus the effective delay (stretch) of the SCL rising edge (Figure 17) plus total delays in the slave’s response data, carried on

Effective delay of SDA at master: 115 + 0.2(Rs \times Cs) + 0.7[(Rb \times Cb) + (Rm \times Cm)] (ns).

C = F; R = Ω.
SDA, reaching the master (Figure 18).

The master microcontroller should be programmed to produce a nominal SCL LOW period as follows:

\[ SCL \text{ LOW} \geq (\text{slave response delay to valid data on its SDA} + A - B + C + \text{data set-up time}) \text{ ns} \]  

(1)

The actual LOW period will become (the programmed value + the stretching time B). When this actual LOW period is then less than the specified minimum, the specified minimum should be used.

**Example 1:**

It is required to connect an Fm+ slave, with Rs \times Cs product of 100 ns, to a 5 V Fast-mode system also having 100 ns Rm \times Cm using two PCA9601’s to buffer a 5 V bus with 4 nF loading and 160 \Omega pull-up.

Calculate the allowed bus speed:

\[
\begin{align*}
\text{Delay A} &= 120 + 85 + (2.5 + [4 \times 4]) \times 5 + 50 = 347.5 \text{ ns} \\
\text{Delay B} &= 115 + 100 + 70 = 285 \text{ ns} \\
\text{Delay C} &= 115 + 20 + 0.7(100 + 100) = 275 \text{ ns}
\end{align*}
\]

The maximum Fm+ slave response delay must be < 450 ns so the programmed LOW period is calculated as:

\[ \text{LOW} \geq 450 + 347.5 - 285 + 275 + 100 = 887.5 \text{ ns} \]

The actual LOW period will be 887.5 + 285 = 1173 ns, which is below the Fast-mode minimum, so the programmed LOW period must be increased to (1300 – 285) = 1015 ns, so the actual LOW equals the 1300 ns requirement and this shows that this Fast-mode system may be safely run to its limit of 400 kHz.

**Example 2:**

It is required to buffer a Master with Fm+ speed capability, but only 3 mA sink capability, to an Fm+ bus. All the system operates at 3.3 V. The Master Rm \times Cm product is 50 ns. Only one PCA9601 is used. The Fm+ bus becomes the buffered bus. The Fm+ bus has 200 pF loading and 150 \Omega pull-up, so its Rb \times Cb product is 30 ns. The Fm+ slave has a specified data valid time \( t_{VD,DAT} \) maximum of 300 ns.

Calculate the allowed maximum system bus speed. (Note that the fixed values in the delay equations represent the internal propagation delays of the PCA9601. Only one PCA9601 is used here, so those fixed values used below are taken from the characteristics.)

The delays are:

\[
\begin{align*}
\text{Delay A} &= 40 + 56 + (2.5 + [4 \times 0.2]) \times 3.3 = 107 \text{ ns} \\
\text{Delay B} &= 115 + 50 + 21 = 186 \text{ ns} \\
\text{Delay C} &= 70 + 0.7(50 + 30) = 126 \text{ ns}
\end{align*}
\]

The programmed LOW period is calculated as:

\[ \text{SCL LOW} \geq 300 + 117 – 186 + 126 + 50 = 407 \text{ ns} \]

The actual LOW period will be 407 + 126 = 533 ns, which exceeds the minimum Fm+ 500 ns requirement. This system requires the bus LOW period, and therefore cycle time, to be increased by 33 ns so the system must run slightly below the 1 MHz limit.
The possible maximum speed has a cycle period of 1033 ns or 968 kHz.

There is an Excel calculator which makes it easy to determine the maximum I²C-bus clock speed when using the PCA9601. The calculator and instructions can be found at www.nxp.com/clockspeedcalculator.
10.2 Negative undershoot below absolute minimum value

The reason why the IC pin reverse voltage on pins TX and RX in Table 5 “Limiting values” is specified at such a low value, −0.3 V, is not that applying larger voltages is likely to cause damage but that it is expected that, in normal applications, there is no reason why larger DC voltages will be applied. This ‘absolute maximum’ specification is intended to be a DC or continuous ratings and the nominal DC I²C-bus voltage LOW usually does not even reach 0 V. Inside PCA9601 at every pin there is a large protective diode connected to the GND pin and that diode will start to conduct when the pin voltage is more than about −0.55 V with respect to GND at 25 °C ambient.

Figure 23 shows the measured characteristic for one of those diodes inside PCA9601. The plot was made using a curve tracer that applies 50 Hz mains voltage via a series resistor, so the pulse durations are long duration (several milliseconds) and are reaching peaks of over 2 A when more than −1.5 V is applied. The IC becomes very hot during this period.
testing but it was not damaged. Whenever there is current flowing in any of these diodes it is possible that there can be faulty operation of any IC. For that reason we put a specification on the negative voltage that is allowed to be applied. It is selected so that, at the highest allowed junction temperature, there will be a big safety factor that guarantees the diode will not conduct and then we do not need to make any 100 % production tests to guarantee the published specification.

For the PCA9601, in specific applications, there will always be transient overshoot and ringing on the wiring that can cause these diodes to conduct. Therefore we designed the IC to withstand those transients and as a part of the qualification procedure we made tests, using DC currents to more than twice the normal bus sink currents, to be sure that the IC was not affected by those currents. For example, the TX/TY and RX/RY pins were tested to at least $-80 \ mA$ which, from Figure 23, would be more than $-0.8 \ V$. The correct functioning of the PCA9601 is not affected even by those large currents. The Absolute Maximum (DC) ratings are not intended to apply to transients but to steady state conditions. This explains why you will never see any problems in practice even if, during transients, more than $-0.3 \ V$ is applied to the bus interface pins of PCA9601.

Figure 23 "Diode characteristic curve" also explains how the general Absolute Maximum DC specification was selected. The current at 25 °C is near zero at $-0.55 \ V$. The PCA9601 is allowed to operate with $+125 \ °C$ junction and that would cause this diode voltage to decrease by $100 \times 2 \ mV = 200 \ mV$. So for zero current we need to specify $-0.35 \ V$ and we publish $-0.3 \ V$ just to have some extra margin.

Remark: You should not be concerned about the transients generated on the wiring by a PCA9601 in normal applications and that is input to the TX/RX or TY/RY pins of another PCA9601. Because not all ICs that may be driven by PCA9601 are designed to tolerate negative transients, in Section 10.2.1 “Example with questions and answers” we show they can be managed if required.

![Diode characteristic curve](image_url)
10.2.1 Example with questions and answers

**Question:** On a falling edge of TX we measure undershoot at −800 mV at the linked TX, RX pins of the PCA9601 that is generating the LOW, but the PCA9601 data sheet specifies minimum −0.3 V. Does this mean that we violate the data sheet absolute value?

**Answer:** For PCA9601 the −0.3 V Absolute Maximum rating is not intended to apply to transients, it is a DC rating. As shown in Figure 24, there is no theoretical reason for any undershoot at the IC that is driving the bus LOW and no significant undershoot should be observed when using reasonable care with the ground connection of the 'scope. It is more likely that undershoot observed at a driving PCA9601 is caused by local stray inductance and capacitance in the circuit and by the oscilloscope connections. As shown, undershoot will be generated by PCB traces, wiring, or cables driven by a PCA9601 because the allowed value of the I2C-bus pull-up resistor generally is larger than that required to correctly terminate the wiring. In this example, with no IC connected at the end of the wiring, the undershoot is about 2 V.

![Fig 24. Transients generated by the bus wiring](image-url)
**Question:** We have 2 meters of cable in a bus that joins the TX/RX sides of two PCA9601 devices. When one TX drives LOW the other PCA9601 TX/RX is driven to $-0.8\,\text{V}$ for over 50 ns. What is the expected value and the theoretically allowed value of undershoot?

**Answer:** Because the cable joining the two PCA9601s is a ‘transmission line’ that will have a characteristic impedance around $100\,\Omega$ and it will be terminated by pull-up resistors that are larger than that characteristic impedance there will always be negative undershoot generated. The duration of the undershoot is a function of the cable length and the input impedance of the connected IC. As shown in Figure 25, the transient undershoot will be limited, by the diodes inside PCA9601, to around $-0.8\,\text{V}$ and that will not cause problems for PCA9601. Those transients will not be passed inside the IC to the SX/SY side of the IC.

![Fig 25. Wiring transients limited by the diodes in PCA9601](image)

**Question:** If we input 800 mV undershoot at TX, RX pins, what kind of problem is expected?

**Answer:** When that undershoot is generated by another PCA9601 and is simply the result of the system wiring, then there will be no problems.

**Question:** Will we have any functional problem or reliability problem?

**Answer:** No.
**Question:** If we add 100 Ω to 200 Ω at signal line, the overshoot becomes slightly smaller. Is this a good idea?

**Answer:** No, it is not necessary to add any resistance. When the logic signal generated by TX or TY of PCA9601 drives long traces or wiring with ICs other than PCA9601 being driven, then adding a Schottky diode (BAT54A) as shown in Figure 26 will clamp the wiring undershoot to a value that will not cause conduction of the IC’s internal diodes.

![Fig 26. Wiring transients limited by a Schottky diode](image-url)
11. Package outline

SO8: plastic small outline package; 8 leads; body width 3.9 mm

---

<table>
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<tr>
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<th>A3</th>
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<th>c</th>
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<th>E(2)</th>
<th>e</th>
<th>Hc</th>
<th>L</th>
<th>Lp</th>
<th>Q</th>
<th>V</th>
<th>W</th>
<th>Y</th>
<th>Z(1)</th>
<th>θ</th>
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<td>0.041</td>
<td>0.016</td>
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<td>0.004</td>
<td>0.028</td>
<td>0.012</td>
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Notes
1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm (0.01 inch) maximum per side are not included.

---

Fig 27. Package outline SOT96-1 (SO8)
TSSOP8: plastic thin shrink small outline package; 8 leads; body width 3 mm

SOT505-1

DIMENSIONS (mm are the original dimensions)

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<th>HE</th>
<th>lP</th>
<th>V</th>
<th>W</th>
<th>Y</th>
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<td>0.4</td>
<td>0.1</td>
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<td>0.70</td>
<td>6°</td>
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<td>0.1</td>
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Notes
1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION

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Fig 28. Package outline SOT505-1 (TSSOP8)
12. Soldering of SMD packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering ICs can be found in Application Note AN10365 “Surface mount reflow soldering description”.

12.1 Introduction to soldering

Soldering is one of the most common methods through which packages are attached to Printed Circuit Boards (PCBs), to form electrical circuits. The soldered joint provides both the mechanical and the electrical connection. There is no single soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and Surface Mount Devices (SMDs) are mixed on one printed wiring board; however, it is not suitable for fine pitch SMDs. Reflow soldering is ideal for the small pitches and high densities that come with increased miniaturization.

12.2 Wave and reflow soldering

Wave soldering is a joining technology in which the joints are made by solder coming from a standing wave of liquid solder. The wave soldering process is suitable for the following:

- Through-hole components
- Leaded or leadless SMDs, which are glued to the surface of the printed circuit board

Not all SMDs can be wave soldered. Packages with solder balls, and some leadless packages which have solder lands underneath the body, cannot be wave soldered. Also, leaded SMDs with leads having a pitch smaller than ~0.6 mm cannot be wave soldered, due to an increased probability of bridging.

The reflow soldering process involves applying solder paste to a board, followed by component placement and exposure to a temperature profile. Leaded packages, packages with solder balls, and leadless packages are all reflow solderable.

Key characteristics in both wave and reflow soldering are:

- Board specifications, including the board finish, solder masks and vias
- Package footprints, including solder thieves and orientation
- The moisture sensitivity level of the packages
- Package placement
- Inspection and repair
- Lead-free soldering versus SnPb soldering

12.3 Wave soldering

Key characteristics in wave soldering are:

- Process issues, such as application of adhesive and flux, clinching of leads, board transport, the solder wave parameters, and the time during which components are exposed to the wave
- Solder bath specifications, including temperature and impurities
12.4 Reflow soldering

Key characteristics in reflow soldering are:

- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see Figure 29) than a SnPb process, thus reducing the process window
- Solder paste printing issues including smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature) and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic). In addition, the peak temperature must be low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with Table 8 and 9.

Table 8. SnPb eutectic process (from J-STD-020D)

<table>
<thead>
<tr>
<th>Package thickness (mm)</th>
<th>Package reflow temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (mm³)</td>
</tr>
<tr>
<td></td>
<td>&lt; 350</td>
</tr>
<tr>
<td></td>
<td>≥ 350</td>
</tr>
<tr>
<td>&lt; 2.5</td>
<td>235</td>
</tr>
<tr>
<td>≥ 2.5</td>
<td>220</td>
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Table 9. Lead-free process (from J-STD-020D)

<table>
<thead>
<tr>
<th>Package thickness (mm)</th>
<th>Package reflow temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (mm³)</td>
</tr>
<tr>
<td></td>
<td>&lt; 350</td>
</tr>
<tr>
<td></td>
<td>350 to 2000</td>
</tr>
<tr>
<td></td>
<td>&gt; 2000</td>
</tr>
<tr>
<td>&lt; 1.6</td>
<td>260</td>
</tr>
<tr>
<td>1.6 to 2.5</td>
<td>260</td>
</tr>
<tr>
<td>&gt; 2.5</td>
<td>250</td>
</tr>
</tbody>
</table>

Moisture sensitivity precautions, as indicated on the packing, must be respected at all times.

Studies have shown that small packages reach higher temperatures during reflow soldering, see Figure 29.
Fig 29. Temperature profiles for large and small components

For further information on temperature profiles, refer to Application Note AN10365 “Surface mount reflow soldering description”.

13. Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>CDM</td>
<td>Charged-Device Model</td>
</tr>
<tr>
<td>ESD</td>
<td>ElectroStatic Discharge</td>
</tr>
<tr>
<td>HBM</td>
<td>Human Body Model</td>
</tr>
<tr>
<td>I²C-bus</td>
<td>Inter-Integrated Circuit bus</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
</tr>
<tr>
<td>MM</td>
<td>Machine Model</td>
</tr>
<tr>
<td>PMBus</td>
<td>Power Management Bus</td>
</tr>
<tr>
<td>SCL</td>
<td>Serial Clock Line</td>
</tr>
<tr>
<td>SDA</td>
<td>Serial DAta line</td>
</tr>
<tr>
<td>SMBus</td>
<td>System Management Bus</td>
</tr>
<tr>
<td>TTL</td>
<td>Transistor-Transistor Logic</td>
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</table>
14. Revision history

Table 11. Revision history

<table>
<thead>
<tr>
<th>Document ID</th>
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<th>Data sheet status</th>
<th>Change notice</th>
<th>Supersedes</th>
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<td>20150924</td>
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Modifications:
- HBM corrected from “4500 V” to “3500 V”. Original material was retested and is 3.5 kV
- Updated Section 4 “Ordering information”
- Table 4 “PCA9601/PCA9600 versus P82B96”: Deleted reference to DIP8 in P82B96 package column

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15. Legal information

15.1 Data sheet status

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<th>Development</th>
<th>This document contains data from the objective specification for product development.</th>
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<tbody>
<tr>
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<td>Qualification</td>
<td>This document contains data from the preliminary specification.</td>
</tr>
<tr>
<td>Product [short] data sheet</td>
<td>Production</td>
<td>This document contains the product specification.</td>
</tr>
</tbody>
</table>

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section “Definitions”.
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

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For sales office addresses, please send an email to: [salesaddresses@nxp.com](mailto:salesaddresses@nxp.com)
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