

# PTN3365

Enhanced performance HDMI/DVI level shifter with active DDC buffer, supporting 3 Gbit/s operation

Rev. 1.1 — 28 July 2015

Product data sheet

## 1. General description

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PTN3365 is a high-speed level shifter device which converts four lanes of low-swing AC-coupled differential input signals to DVI v1.0 and HDMI v1.4b compliant open-drain current-steering differential output signals, up to 3.0 Gbit/s per lane to support 36-bit deep color mode, 4K × 2K video format or 3D video data transport. Each of these lanes provides a level-shifting differential buffer to translate from low-swing AC-coupled differential signaling on the source side, to TMDS-type DC-coupled differential current-mode signaling terminated into 50 Ω to 3.3 V on the sink side. Additionally, PTN3365 provides a single-ended active buffer for voltage translation of the HPD signal from 5 V on the sink side to 3.3 V on the source side and provides a channel with active buffering and level shifting of the DDC channel (consisting of a clock and a data line) between 3.3 V source-side and 5 V sink-side. The DDC channel is implemented using active I<sup>2</sup>C-bus buffer technology providing capacitive isolation, redriving and level shifting as well as disablement (isolation between source and sink) of the clock and data lines.

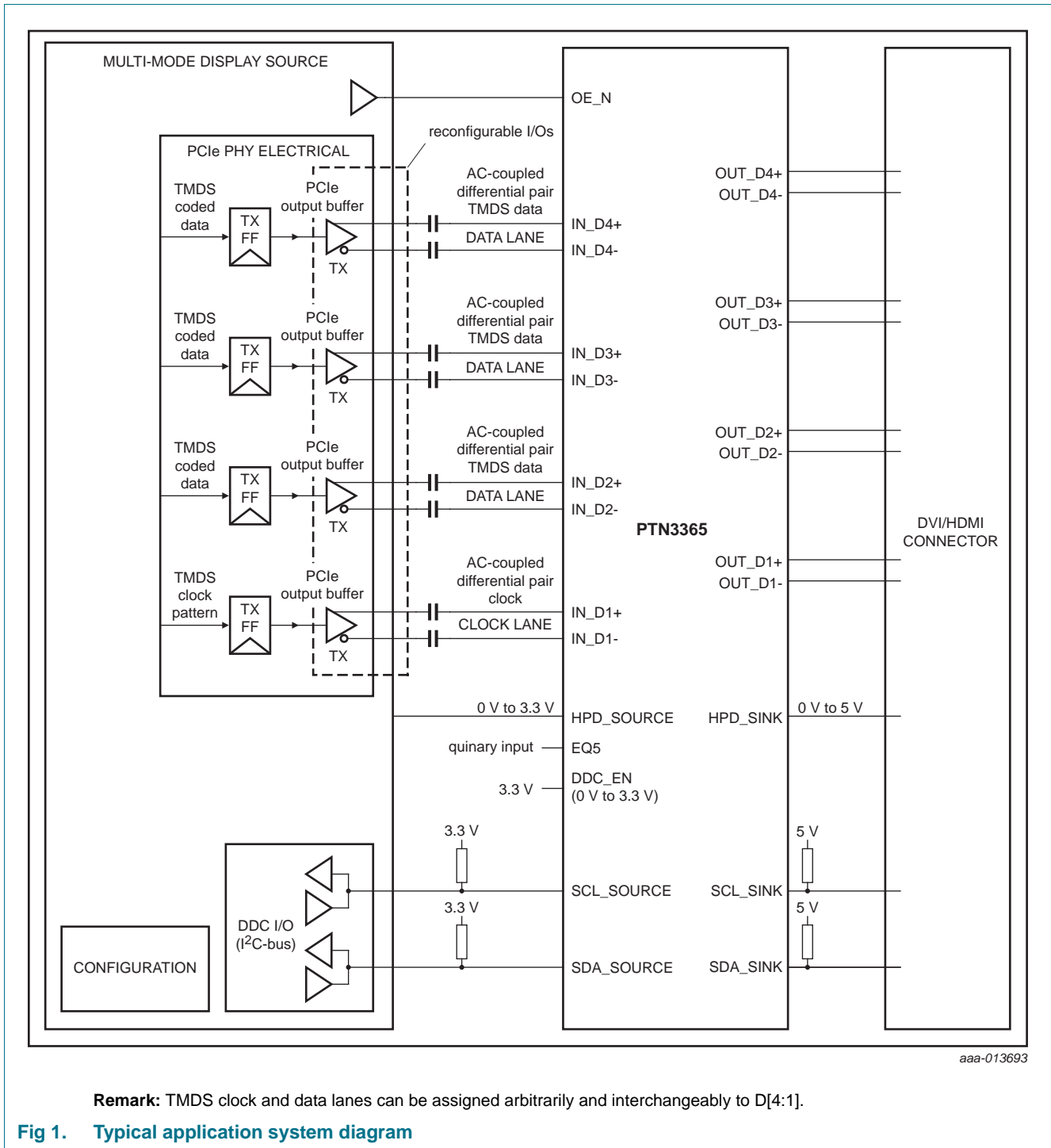
The low-swing AC-coupled differential input signals to PTN3365 typically come from a display source with multi-mode I/O, which supports multiple display standards, for example, DisplayPort, HDMI and DVI. While the input differential signals are configured to carry DVI or HDMI coded data, they do not comply with the electrical requirements of the DVI v1.0 or HDMI v1.4b specification. By using PTN3365, chip set vendors are able to implement such reconfigurable I/Os on multi-mode display source devices, allowing the support of multiple display standards while keeping the number of chip set I/O pins low. See [Figure 1](#).

PTN3365 features low-swing self-biasing differential inputs which are compliant to the electrical specifications of *DisplayPort Standard v1.2* and/or *PCI Express Standard v1.1*, and open-drain current-steering differential outputs compliant to DVI v1.0 and HDMI v1.4b electrical specifications. The I<sup>2</sup>C-bus channel actively buffers as well as level-translates the DDC signals for optimal capacitive isolation. PTN3365 also supports power-saving modes in order to minimize current consumption when no display is active or connected.

PTN3365 is a full-featured HDMI and DVI level shifter.

PTN3365 is powered from a single 3.3 V power supply consuming a small amount of power (230 mW typical) and is offered in a 32-terminal HVQFN32 package.





## 2. Features and benefits

### 2.1 High-speed TMDS level shifting

- Converts four lanes of low-swing AC-coupled differential input signals to DVI v1.0 and HDMI v1.4b compliant open-drain current-steering differential output signals
- TMDS level shifting operation up to 3.0 Gbit/s per lane supporting 4K × 2K and 3D video formats
- Programmable equalizer
- Integrated 50 Ω termination resistors for self-biasing differential inputs
- Back-current safe outputs to disallow current when device power is off and monitor is on
- Disable feature to turn off TMDS inputs and outputs and to enter low-power state

### 2.2 DDC level shifting

- Integrated DDC buffering and level shifting (3.3 V source to 5 V sink side)
- Rise time accelerator on sink-side DDC ports
- 0 Hz to 400 kHz I<sup>2</sup>C-bus clock frequency
- Back-power safe sink-side terminals to disallow backdrive current when power is off or when DDC is not enabled

### 2.3 HPD level shifting

- HPD non-inverting level shift from 0 V on the sink side to 0 V on the source side, or from 5 V on the sink side to 3.3 V on the source side
- Integrated 200 kΩ pull-down resistor on HPD sink input guarantees 'input LOW' when no display is plugged in
- Back-power safe design on HPD\_SINK to disallow backdrive current when power is off

### 2.4 General

- Power supply 3.0 V to 3.6 V
- ESD resilience to 6 kV HBM, 1 kV CDM
- Power-saving modes (using output enable)
- Back-current-safe design on all sink-side main link, DDC and HPD terminals
- Transparent operation: no re-timing or software configuration required
- 32-terminal HVQFN32 package

## 3. Applications

- PC motherboard/graphics card
- Docking station
- DisplayPort to HDMI adapters supporting 4K × 2K and 3D video formats
- DisplayPort to DVI adapters required to drive long cables

## 4. Ordering information

Table 1. Ordering information

| Type number | Topside mark | Package |  |          |
|-------------|--------------|---------|--|----------|
|             |              | Name    | Description  | Version  |
| PTN3365BS   | P3365        | HVQFN32 | plastic thermal enhanced very thin quad flat package; no leads; 32 terminals; body 5 x 5 x 0.85 mm | SOT617-3 |

### 4.1 Ordering options

Table 2. Ordering options

| Type number | Orderable part number | Package | Packing method                                | Minimum order quantity | Temperature range                   |
|-------------|-----------------------|---------|---|------------------------|-------------------------------------|
| PTN3365BS   | PTN3365BSMP           | HVQFN32 | Reel 13" Q2/T3<br>*standard mark SMD dry pack | 6000                   | T <sub>amb</sub> = -40 °C to +85 °C |

5. Functional diagram

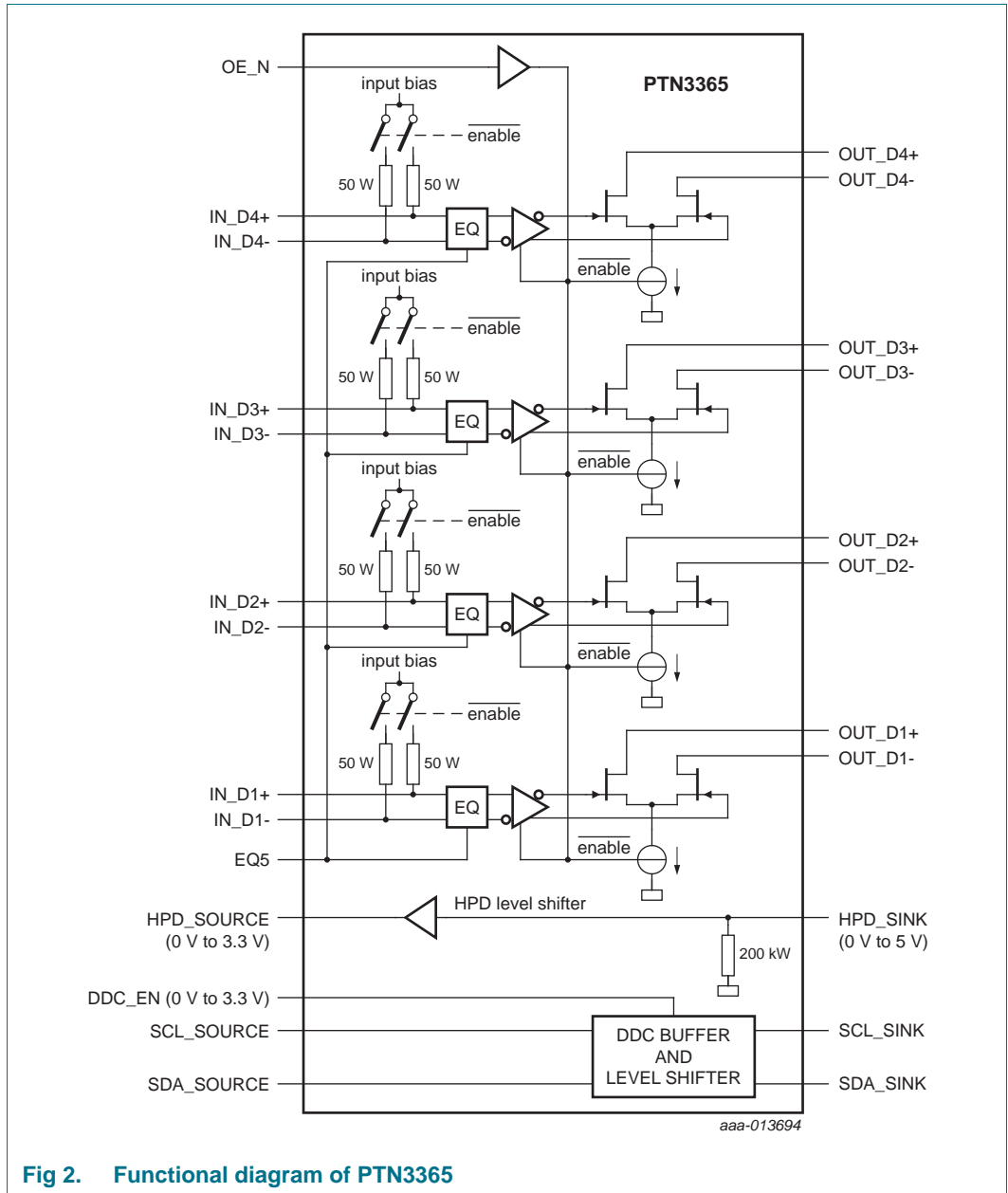
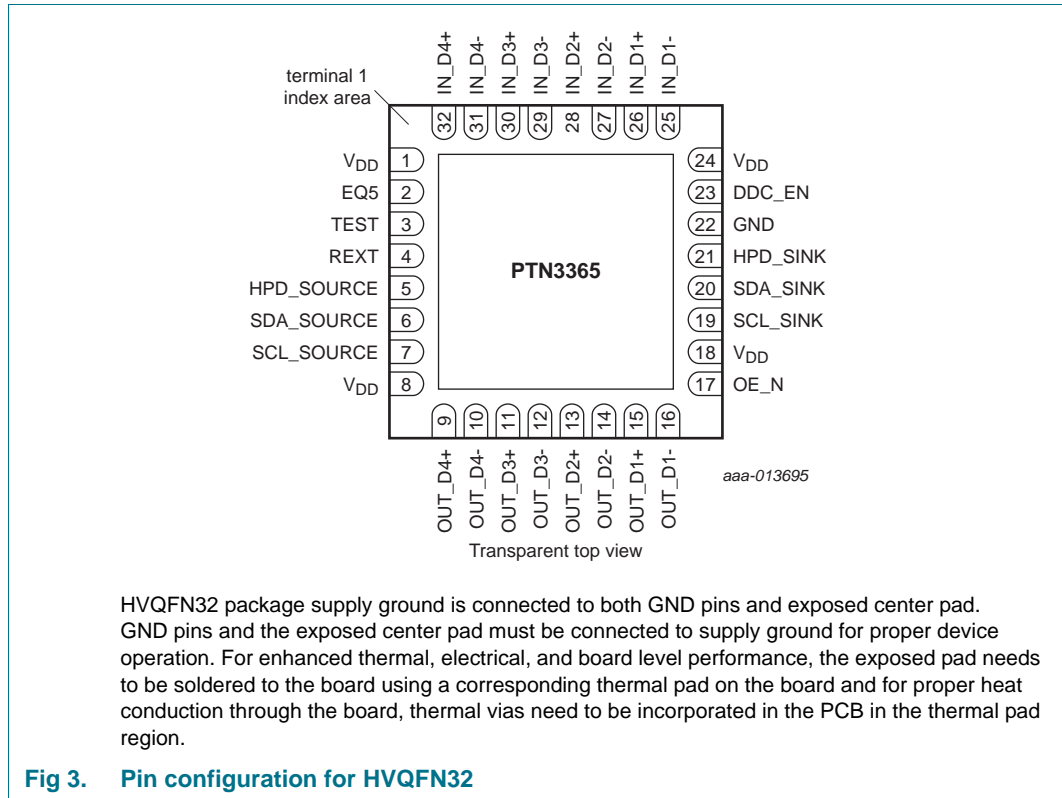


Fig 2. Functional diagram of PTN3365

## 6. Pinning information

### 6.1 Pinning



### 6.2 Pin description

Table 3. Pin description

| Symbol                                | Pin | Type                                      | Description   |
|---------------------------------------|-----|---|---|
| <b>OE_N, IN_Dx and OUT_Dx signals</b> |     |   |   |
| OE_N                                  | 17  | 3.3 V low-voltage CMOS single-ended input | Output Enable and power saving function for high-speed differential level shifter path.<br>When OE_N = HIGH:<br>IN_Dx termination = high-impedance<br>OUT_Dx outputs = high-impedance; zero output current<br>When OE_N = LOW:<br>IN_Dx termination = 50 Ω<br>OUT_Dx outputs = active |
| IN_D4+                                | 32  | Self-biasing differential input           | Low-swing differential input from display source with PCI Express electrical signaling. IN_D4+ makes a differential pair with IN_D4-. The input to this pin must be AC coupled externally.  |

Table 3. Pin description ...continued

| Symbol  | Pin | Type                            | Description  |
|---------|-----|---------------------------------|--|
| IN_D4-  | 31  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D4- makes a differential pair with IN_D4+. The input to this pin must be AC coupled externally. |
| IN_D3+  | 30  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D3+ makes a differential pair with IN_D3-. The input to this pin must be AC coupled externally. |
| IN_D3-  | 29  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D3- makes a differential pair with IN_D3+. The input to this pin must be AC coupled externally. |
| IN_D2+  | 28  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D2+ makes a differential pair with IN_D2-. The input to this pin must be AC coupled externally. |
| IN_D2-  | 27  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D2- makes a differential pair with IN_D2+. The input to this pin must be AC coupled externally. |
| IN_D1+  | 26  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D1+ makes a differential pair with IN_D1-. The input to this pin must be AC coupled externally. |
| IN_D1-  | 25  | Self-biasing differential input | Low-swing differential input from display source with PCI Express electrical signaling. IN_D1- makes a differential pair with IN_D1+. The input to this pin must be AC coupled externally. |
| OUT_D4+ | 9   | TMDS differential output        | HDMI compliant TMDS output. OUT_D4+ makes a differential pair with OUT_D4-. OUT_D4+ is in phase with IN_D4+.   |
| OUT_D4- | 10  | TMDS differential output        | HDMI compliant TMDS output. OUT_D4- makes a differential pair with OUT_D4+. OUT_D4- is in phase with IN_D4-.   |
| OUT_D3+ | 11  | TMDS differential output        | HDMI compliant TMDS output. OUT_D3+ makes a differential pair with OUT_D3-. OUT_D3+ is in phase with IN_D3+.   |
| OUT_D3- | 12  | TMDS differential output        | HDMI compliant TMDS output. OUT_D3- makes a differential pair with OUT_D3+. OUT_D3- is in phase with IN_D3-.   |
| OUT_D2+ | 13  | TMDS differential output        | HDMI compliant TMDS output. OUT_D2+ makes a differential pair with OUT_D2-. OUT_D2+ is in phase with IN_D2+.   |

Table 3. Pin description ...continued

| Symbol                     | Pin          | Type                                  | Description   |
|----------------------------|--------------|---------------------------------------|---|
| OUT_D2-                    | 14           | TMDS differential output              | HDMI compliant TMDS output. OUT_D2- makes a differential pair with OUT_D2+. OUT_D2- is in phase with IN_D2-.  |
| OUT_D1+                    | 15           | TMDS differential output              | HDMI compliant TMDS output. OUT_D1+ makes a differential pair with OUT_D1-. OUT_D1+ is in phase with IN_D1+.  |
| OUT_D1-                    | 16           | TMDS differential output              | HDMI compliant TMDS output. OUT_D1- makes a differential pair with OUT_D1+. OUT_D1- is in phase with IN_D1-.  |
| <b>HPD and DDC signals</b> |              |                                       |   |
| HPD_SINK                   | 21           | 5 V CMOS single-ended input           | 0 V to 5 V (nominal) input signal. This signal comes from the DVI or HDMI sink. A HIGH value indicates that the sink is connected; a LOW value indicates that the sink is disconnected. HPD_SINK is pulled down by an integrated 200 k $\Omega$ pull-down resistor. |
| HPD_SOURCE                 | 5            | 3.3 V CMOS single-ended output        | 0 V to 3.3 V (nominal) output signal. This is level-shifted version of the HPD_SINK signal.   |
| SCL_SOURCE                 | 7            | single-ended 3.3 V open-drain DDC I/O | 3.3 V source-side DDC clock I/O. Pulled up by external termination to 3.3 V. 5 V tolerant I/O.  |
| SDA_SOURCE                 | 6            | single-ended 3.3 V open-drain DDC I/O | 3.3 V source-side DDC data I/O. Pulled up by external termination to 3.3 V. 5 V tolerant I/O.   |
| SCL_SINK                   | 19           | single-ended 5 V open-drain DDC I/O   | 5 V sink-side DDC clock I/O. Pulled up by external termination to 5 V. Provides rise time acceleration for LOW-to-HIGH transitions.   |
| SDA_SINK                   | 20           | single-ended 5 V open-drain DDC I/O   | 5 V sink-side DDC data I/O. Pulled up by external termination to 5 V. Provides rise time acceleration for LOW-to-HIGH transitions.  |
| DDC_EN                     | 23           | 3.3 V CMOS input                      | Enables the DDC buffer and level shifter. When DDC_EN = LOW, buffer/level shifter is disabled. When DDC_EN = HIGH, buffer and level shifter are enabled.  |
| TEST                       | 3            | 3.3 V CMOS input                      | This is a test pin and it shall always be connected to GND in the system applications.  |
| <b>Supply and ground</b>   |              |                                       |   |
| V <sub>DD</sub>            | 1, 8, 18, 24 | 3.3 V DC supply                       | Supply voltage; 3.3 V $\pm$ 10 %.   |
| GND <sup>[1]</sup>         | 22           | ground                                | Supply ground. All GND pins must be connected to ground for proper operation.   |



Table 3. Pin description ...continued

| Symbol                         | Pin | Type                                 | Description  |
|--------------------------------|-----|--------------------------------------|--|
| <b>Feature control signals</b> |     |                                      |  |
| REXT                           | 4   | analog I/O                           | Current sense port used to provide an accurate current reference for the differential outputs OUT_Dx. For best output voltage swing accuracy, use of a 10 kΩ resistor (1 % tolerance) from this terminal to GND is recommended. May also be tied to either V <sub>DD</sub> or GND directly (0 Ω). See <a href="#">Section 7.2</a> for details. |
| EQ5                            | 2   | 3.3 V low-voltage CMOS quinary input | Equalizer setting input pin. This pin can be board-strapped to one of five decode values: short to GND, resistor to GND, open-circuit, resistor to V <sub>DD</sub> , short to V <sub>DD</sub> . See <a href="#">Table 5</a> for truth table.   |

[1] HVQFN32 package supply ground is connected to both GND pins and exposed center pad. GND pins and the exposed center pad must be connected to supply ground for proper device operation. For enhanced thermal, electrical, and board level performance, the exposed pad needs to be soldered to the board using a corresponding thermal pad on the board and for proper heat conduction through the board, thermal vias need to be incorporated in the PCB in the thermal pad region.

## 7. Functional description

Refer to [Figure 2 “Functional diagram of PTN3365”](#).

PTN3365 level shifts four lanes of low-swing AC-coupled differential input signals to DVI and HDMI compliant open-drain current-steering differential output signals, up to 3.0 Gbit/s per lane to support 36-bit deep color mode. It has integrated 50  $\Omega$  termination resistors for AC-coupled differential input signals. An enable signal OE\_N can be used to turn off the TMDS inputs and outputs, thereby minimizing power consumption. The TMDS outputs are back-power safe to disallow current flow from a powered sink while PTN3365 is unpowered.

PTN3365's DDC channel provides active level shifting and buffering, allowing 3.3 V source-side termination and 5 V sink-side termination. The sink-side DDC ports are equipped with a rise time accelerator enabling drive of long cables or high bus capacitance. This enables the system designer to isolate bus capacitance to meet/exceed HDMI DDC specification. PTN3365 offers back-power safe sink-side I/Os to disallow backdrive current from the DDC clock and data lines when power is off or when DDC is not enabled. An enable signal DCC\_EN enables the DDC level shifter block.

PTN3365 also provides voltage translation for the Hot Plug Detect (HPD) signal from 0 V to 5 V on the sink side to 0 V to 3.3 V on the source side.

PTN3365 does not re-time any data. It contains no state machines. No inputs or outputs of the device are latched or clocked. Because PTN3365 acts as a transparent level shifter, no reset is required.

### 7.1 Enable and disable features

PTN3365 offers different ways to enable or disable functionality, using the Output Enable (OE\_N), and DDC Enable (DCC\_EN) inputs. Whenever PTN3365 is disabled, the device will be in Standby mode and power consumption will be minimal; otherwise PTN3365 will be in active mode and power consumption will be nominal. These two inputs each affect the operation of PTN3365 differently: OE\_N controls the TMDS channels, DCC\_EN affects only the DDC channel, and HPD\_SINK does not affect either of the channels. The following sections and truth table describe their detailed operation.

#### 7.1.1 Hot plug detect

The HPD channel of PTN3365 functions as a level-shifting buffer to pass the HPD logic signal from the display sink device (via input HPD\_SINK) on to the display source device (via output HPD\_SOURCE).

The output logic state of HPD\_SOURCE output always follows the logic state of input HPD\_SINK, regardless of whether the device is in Active mode or Standby mode.

### 7.1.2 Output Enable function (OE\_N)

When input OE\_N is asserted (active LOW), the IN\_Dx and OUT\_Dx signals are fully functional. Input termination resistors are enabled and the internal bias circuits are turned on.

When OE\_N is de-asserted (inactive HIGH), the OUT\_Dx outputs are in a high-impedance state and drive zero output current. The IN\_Dx input buffers are disabled and IN\_Dx termination is disabled. Power consumption is minimized.

**Remark:** Note that OE\_N signal level has no influence on the HPD\_SINK input, HPD\_SOURCE output, or the SCL and SDA level shifters. A transition from HIGH to LOW at OE\_N may disable the DDC channel for up to 20  $\mu$ s.

### 7.1.3 DDC channel enable function (DDC\_EN)

The DDC\_EN pin is active HIGH and can be used to isolate a badly behaved slave. When DDC\_EN is LOW, the DDC channel is turned off. The DDC\_EN input should never change state during an I<sup>2</sup>C-bus operation. Note that disabling DDC\_EN during a bus operation may hang the bus, while enabling DDC\_EN during bus traffic would corrupt the I<sup>2</sup>C-bus operation. Hence, DDC\_EN should only be toggled while the bus is idle. (See I<sup>2</sup>C-bus specification).

7.1.4 Enable/disable truth table

Table 4. HPD\_SINK, OE\_N and DDC\_EN enabling truth table

| Inputs   |             |               | Channels                                  |                                     |   |               | Mode                 |
|----------|-------------|---------------|---|-------------------------------------|---|---------------|----------------------|
| HPD_SINK | OE_N<br>[1] | DDC_EN<br>[2] | IN_Dx                                     | OUT_Dx[3]                           | DDC[4]  | HPD_SOURCE[5] |                      |
| LOW      | LOW         | LOW           | 50 Ω termination to V <sub>RX(bias)</sub> | enabled                             | high-impedance  | LOW           | Active; DDC disabled |
| LOW      | LOW         | HIGH          | 50 Ω termination to V <sub>RX(bias)</sub> | enabled                             | SDA_SINK connected to SDA_SOURCE and SCL_SINK connected to SCL_SOURCE | LOW           | Active; DDC enabled  |
| LOW      | HIGH        | LOW           | high-impedance                            | high-impedance; zero output current | high-impedance  | LOW           | Standby              |
| LOW      | HIGH        | HIGH          | high-impedance                            | high-impedance; zero output current | SDA_SINK connected to SDA_SOURCE and SCL_SINK connected to SCL_SOURCE | LOW           | Standby; DDC enabled |
| HIGH     | LOW         | LOW           | 50 Ω termination to V <sub>RX(bias)</sub> | enabled                             | high-impedance  | HIGH          | Active; DDC disabled |
| HIGH     | LOW         | HIGH          | 50 Ω termination to V <sub>RX(bias)</sub> | enabled                             | SDA_SINK connected to SDA_SOURCE and SCL_SINK connected to SCL_SOURCE | HIGH          | Active; DDC enabled  |
| HIGH     | HIGH        | LOW           | high-impedance                            | high-impedance; zero output current | high-impedance  | HIGH          | Standby              |
| HIGH     | HIGH        | HIGH          | high-impedance                            | high-impedance; zero output current | SDA_SINK connected to SDA_SOURCE and SCL_SINK connected to SCL_SOURCE | HIGH          | Standby; DDC enabled |

- [1] A HIGH level on input OE\_N disables only the TMDS channels. A transition from HIGH to LOW at OE\_N may disable the DDC channel for up to 20 μs.
- [2] A LOW level on input DDC\_EN disables only the DDC channel.
- [3] OUT\_Dx channels 'enabled' means outputs OUT\_Dx toggling in accordance with IN\_Dx differential input voltage switching.
- [4] DDC channel 'enabled' means SDA\_SINK is connected to SDA\_SOURCE and SCL\_SINK is connected to SCL\_SOURCE.
- [5] The HPD\_SOURCE output logic state always follows the HPD\_SINK input logic state.

## 7.2 Analog current reference

The REXT pin (pin 6) is an analog current sense port used to provide an accurate current reference for the differential outputs OUT\_Dx. For best output voltage swing accuracy, use of a 10 k $\Omega$  resistor (1 % tolerance) connected between this terminal and GND is recommended.

If an external 10 k $\Omega$   $\pm$  1 % resistor is not used, this pin can be connected to GND or V<sub>DD</sub> directly (0  $\Omega$ ). In any of these cases, the output will function normally but at reduced accuracy over voltage and temperature of the following parameters: output levels (V<sub>OL</sub>), differential output voltage swing, and rise and fall time accuracy.

## 7.3 Equalizer

PTN3365 supports 5 level equalization setting by the quinary input pin EQ5.

**Table 5. Equalizer settings**

| Inputs                                    | Quinary notation | Equalizer mode |
|---|------------------|----------------|
| <b>EQ5</b>                                |                  |                |
| short to GND                              | 0 <sub>5</sub>   | 0 dB           |
| 10 k $\Omega$ resistor to GND             | 1 <sub>5</sub>   | 2 dB           |
| open-circuit                              | 2 <sub>5</sub>   | 3.5 dB         |
| 10 k $\Omega$ resistor to V <sub>DD</sub> | 3 <sub>5</sub>   | 9 dB           |
| short to V <sub>DD</sub>                  | 4 <sub>5</sub>   | 7 dB           |

## 7.4 Backdrive current protection

PTN3365 is designed for backdrive prevention on all sink-side TMDS outputs, sink-side DDC I/Os and the HPD\_SINK input. This supports user scenarios where the display is connected and powered, but PTN3365 is unpowered. In these cases, PTN3365 will sink no more than a negligible amount of leakage current, and will block the display (sink) termination network from driving the power supply of PTN3365 or that of the inactive DVI or HDMI source.

## 7.5 Active DDC buffer with rise time accelerator

PTN3365 DDC channel, besides providing 3.3 V to 5 V level shifting, includes active buffering and rise time acceleration which allows up to 18 meters bus extension for reliable DDC applications. While retaining all the operating modes and features of the I<sup>2</sup>C-bus system during the level shifts, it permits extension of the I<sup>2</sup>C-bus by providing bidirectional buffering for both the data (SDA) and the clock (SCL) line as well as the rise time accelerator on the sink-side port (SCL\_SINK and SDA\_SINK) enabling the bus to drive a load up to 1400 pF or distance of 18 m on the sink-side port, and 400 pF on the source-side port (SCL\_SOURCE and SCA\_SOURCE). Using PTN3365 for DVI or HDMI level shifting enables the system designer to isolate bus capacitance to meet/exceed HDMI DDC specification. The SDA and SCL pins are overvoltage tolerant and are high-impedance when PTN3365 is unpowered or when DDC\_EN is LOW.

PTN3365 has rise time accelerators on the sink-side port (SCL\_SINK and SDA\_SINK) only. During positive bus transitions on the sink-side port, a current source is switched on to quickly slew the SCL\_SINK and SDA\_SINK lines HIGH once the 5 V DDC bus  $V_{IL}$  threshold level of around 1.5 V is exceeded, and turns off as the 5 V DDC bus  $V_{IH}$  threshold voltage of approximately 3.5 V is approached.

## 8. Limiting values

**Table 6. Limiting values**

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

| Symbol    | Parameter                       | Conditions        | Min   | Max            | Unit |
|-----------|---------------------------------|-------------------|-------|----------------|------|
| $V_{DD}$  | supply voltage                  |                   | -0.3  | +4.6           | V    |
| $V_I$     | input voltage                   | 3.3 V CMOS inputs | -0.3  | $V_{DD} + 0.5$ | V    |
|           |                                 | 5.0 V CMOS inputs | -0.3  | 6.0            | V    |
| $T_{stg}$ | storage temperature             |                   | -65   | +150           | °C   |
| $V_{ESD}$ | electrostatic discharge voltage | HBM               | [1] - | 6000           | V    |
|           |                                 | CDM               | [2] - | 1000           | V    |

[1] Human Body Model: ANSI/EOS/ESD-S5.1-1994, standard for ESD sensitivity testing, Human Body Model - Component level; Electrostatic Discharge Association, Rome, NY, USA.

[2] Charged Device Model: ANSI/EOS/ESD-S5.3-1-1999, standard for ESD sensitivity testing, Charged Device Model - Component level; Electrostatic Discharge Association, Rome, NY, USA.

## 9. Recommended operating conditions

**Table 7. Recommended operating conditions**

| Symbol         | Parameter                     | Conditions                                 | Min   | Typ          | Max | Unit       |
|----------------|-------------------------------|--|-------|--------------|-----|------------|
| $V_{DD}$       | supply voltage                |  | 3.0   | 3.3          | 3.6 | V          |
| $V_I$          | input voltage                 | 3.3 V CMOS inputs                          | 0     | -            | 3.6 | V          |
|                |                               | 5.0 V CMOS inputs                          | 0     | -            | 5.5 | V          |
| $V_{I(AV)}$    | average input voltage         | IN_Dn+, IN_Dn- inputs                      | [1] - | 0            | -   | V          |
| $R_{ref(ext)}$ | external reference resistance | connected between pin REXT (pin 6) and GND | [2] - | $10 \pm 1\%$ | -   | k $\Omega$ |
| $T_{amb}$      | ambient temperature           | operating in free air                      | -40   | -            | +85 | °C         |

[1] Input signals to these pins must be AC-coupled.

[2] Operation without external reference resistor is possible but will result in reduced output voltage swing accuracy. For details, see [Section 7.2](#).

### 9.1 Current consumption

**Table 8. Current consumption**

| Symbol   | Parameter      | Conditions                            | Min | Typ | Max | Unit |
|----------|----------------|---------------------------------------|-----|-----|-----|------|
| $I_{DD}$ | supply current | OE_N = 0; Active mode                 | -   | 70  | 100 | mA   |
|          |                | OE_N = 1 and DDC_EN = 0; Standby mode | -   | -   | 5   | mA   |

## 10. Characteristics

### 10.1 Differential inputs

Table 9. Differential input characteristics for IN\_Dx signals

| Symbol                  | Parameter                               | Conditions                            |                | Min   | Typ | Max   | Unit |
|-------------------------|---|---------------------------------------|----------------|-------|-----|-------|------|
| UI                      | unit interval <sup>[1]</sup>            |                                       | <sup>[2]</sup> | 333   | -   | 4000  | ps   |
| V <sub>RX_DIFFp-p</sub> | differential input peak-to-peak voltage |                                       | <sup>[3]</sup> | 0.175 | -   | 1.200 | V    |
| t <sub>RX_EYE</sub>     | receiver eye time                       | minimum eye width at IN_Dx input pair |                | 0.8   | -   | -     | UI   |
| V <sub>i(cm)M(AC)</sub> | peak common-mode input voltage (AC)     | includes all frequencies above 30 kHz | <sup>[4]</sup> | -     | -   | 100   | mV   |
| Z <sub>RX_DC</sub>      | DC input impedance                      |                                       |                | 40    | 50  | 60    | Ω    |
| V <sub>RX(bias)</sub>   | bias receiver voltage                   |                                       |                | 1.0   | 1.2 | 1.4   | V    |
| Z <sub>I(se)</sub>      | single-ended input impedance            | inputs in high-impedance state        | <sup>[5]</sup> | 100   | -   | -     | kΩ   |

[1] UI (unit interval) = t<sub>bit</sub> (bit time).

[2] UI is determined by the display mode. Nominal bit rate ranges from 250 Mbit/s to 3.0 Gbit/s per lane.

[3] V<sub>RX\_DIFFp-p</sub> = 2 × |V<sub>RX\_D+</sub> - V<sub>RX\_D-</sub>|. Applies to IN\_Dx signals.

[4] V<sub>i(cm)M(AC)</sub> = |V<sub>RX\_D+</sub> + V<sub>RX\_D-</sub>| / 2 - V<sub>RX(cm)</sub>.  
V<sub>RX(cm)</sub> = DC (avg) of |V<sub>RX\_D+</sub> + V<sub>RX\_D-</sub>| / 2.

[5] Differential inputs will switch to a high-impedance state when OE\_N is HIGH.

### 10.2 Differential outputs

The level shifter's differential outputs are designed to meet HDMI version 1.4a and DVI version 1.0 specifications.

Table 10. Differential output characteristics for OUT\_Dx signals

| Symbol                | Parameter                              | Conditions  |                | Min                    | Typ                    | Max                    | Unit |
|-----------------------|--|---|----------------|------------------------|------------------------|------------------------|------|
| V <sub>OH(se)</sub>   | single-ended HIGH-level output voltage |   | <sup>[1]</sup> | V <sub>TT</sub> - 0.01 | V <sub>TT</sub>        | V <sub>TT</sub> + 0.01 | V    |
| V <sub>OL(se)</sub>   | single-ended LOW-level output voltage  |   | <sup>[2]</sup> | V <sub>TT</sub> - 0.60 | V <sub>TT</sub> - 0.50 | V <sub>TT</sub> - 0.40 | V    |
| ΔV <sub>O(se)</sub>   | single-ended output voltage variation  | logic 1 and logic 0 state applied respectively to differential inputs IN_Dn; R <sub>ref(ext)</sub> connected; see <a href="#">Table 7</a> | <sup>[3]</sup> | 400                    | 500                    | 600                    | mV   |
| I <sub>OZ</sub>       | OFF-state output current               | single-ended  |                | -                      | -                      | 10                     | μA   |
| t <sub>r</sub>        | rise time                              | 20 % to 80 %  |                | 75                     | -                      | 240                    | ps   |
| t <sub>f</sub>        | fall time                              | 80 % to 20 %  |                | 75                     | -                      | 240                    | ps   |
| t <sub>sk</sub>       | skew time                              | intra-pair  | <sup>[4]</sup> | -                      | -                      | 10                     | ps   |
|                       |  | inter-pair  | <sup>[5]</sup> | -                      | -                      | 250                    | ps   |
| t <sub>jit(add)</sub> | added jitter time                      | jitter contribution   | <sup>[6]</sup> | -                      | 10                     | -                      | ps   |

[1] V<sub>TT</sub> is the DC termination voltage in the HDMI or DVI sink. V<sub>TT</sub> is nominally 3.3 V.

[2] The open-drain output pulls down from V<sub>TT</sub>.

[3] Swing down from TMDS termination voltage (3.3 V ± 10 %).

- [4] This differential skew budget is in addition to the skew presented between IN\_D+ and IN\_D- paired input pins.  
 [5] This lane-to-lane skew budget is in addition to skew between differential input pairs.  
 [6] Jitter budget for differential signals as they pass through the level shifter.

### 10.3 HPD\_SINK input, HPD\_SOURCE output

Table 11. HPD characteristics

| Symbol          | Parameter                 | Conditions                                   |     | Min | Typ | Max             | Unit |
|-----------------|---------------------------|--|-----|-----|-----|-----------------|------|
| V <sub>IH</sub> | HIGH-level input voltage  | HPD_SINK                                     | [1] | 2.0 | 5.0 | 5.3             | V    |
| V <sub>IL</sub> | LOW-level input voltage   | HPD_SINK                                     |     | 0   | -   | 0.8             | V    |
| I <sub>LI</sub> | input leakage current     | HPD_SINK                                     |     | -   | -   | 15              | μA   |
| V <sub>OH</sub> | HIGH-level output voltage | HPD_SOURCE                                   |     | 2.5 | -   | V <sub>DD</sub> | V    |
| V <sub>OL</sub> | LOW-level output voltage  | HPD_SOURCE                                   |     | 0   | -   | 0.2             | V    |
| t <sub>PD</sub> | propagation delay         | from HPD_SINK to HPD_SOURCE;<br>50 % to 50 % | [2] | -   | -   | 200             | ns   |
| t <sub>t</sub>  | transition time           | HPD_SOURCE rise/fall; 10 % to 90 %           | [3] | 1   | -   | 20              | ns   |
| R <sub>pd</sub> | pull-down resistance      | HPD_SINK input pull-down resistor            | [4] | 100 | 200 | 300             | kΩ   |

- [1] Low-speed input changes state on cable plug/unplug.  
 [2] Time from HPD\_SINK changing state to HPD\_SOURCE changing state. Includes HPD\_SOURCE rise/fall time.  
 [3] Time required to transition from V<sub>OH</sub> to V<sub>OL</sub> or from V<sub>OL</sub> to V<sub>OH</sub>.  
 [4] Guarantees HPD\_SINK is LOW when no display is plugged in.

### 10.4 OE\_N, DDC\_EN and test inputs

Table 12. OE\_N, DDC\_EN input characteristics

| Symbol          | Parameter                | Conditions |     | Min | Typ | Max | Unit |
|-----------------|--------------------------|------------|-----|-----|-----|-----|------|
| V <sub>IH</sub> | HIGH-level input voltage |            |     | 2.0 | -   |     | V    |
| V <sub>IL</sub> | LOW-level input voltage  |            |     |     | -   | 0.8 | V    |
| I <sub>LI</sub> | input leakage current    | OE_N pin   | [1] | -   | -   | 10  | μA   |

- [1] Measured with input at V<sub>IH</sub> maximum and V<sub>IL</sub> minimum.



## 10.5 DDC characteristics

Table 13. DDC characteristics

| Symbol   | Parameter  | Conditions   | Min          | Typ  | Max  | Unit          |
|--|--|--|--------------|------|------|---------------|
| <b>Input and output SCL_SOURCE and SDA_SOURCE, <math>V_{CC1} = 3.0\text{ V to }3.6\text{ V}</math> [1]</b> |  |  |              |      |      |               |
| $V_{IH}$   | HIGH-level input voltage   |  | $0.7V_{CC1}$ | -    | 3.6  | V             |
| $V_{ILc}$  | contention LOW-level input voltage   | guaranteed by design   | -0.5         | -    | 0.4  | V             |
| $I_{LI}$   | input leakage current  | $V_I = 3.6\text{ V}$   | -            | -    | 10   | $\mu\text{A}$ |
| $I_{IL}$   | LOW-level input current  | $V_I = 0.2\text{ V}$   | -            | -    | 10   | $\mu\text{A}$ |
| $V_{OL}$   | LOW-level output voltage   | $I_{OL} = 6\text{ mA}$   | [2] 0.47     | 0.52 | 0.6  | V             |
| $V_{OL} - V_{ILc}$   | difference between LOW-level output and LOW-level input voltage contention | guaranteed by design   | -            | -    | 70   | mV            |
| $C_{io}$   | input/output capacitance   | $V_I = 3\text{ V or }0\text{ V}; V_{DD} = 3.3\text{ V}$              | -            | 6    | 7    | pF            |
|  |  | $V_I = 3\text{ V or }0\text{ V}; V_{DD} = 0\text{ V}$                | -            | 6    | 7    | pF            |
| <b>Input and output SDA_SINK and SCL_SINK, <math>V_{CC2} = 4.5\text{ V to }5.5\text{ V}</math> [3]</b>     |  |  |              |      |      |               |
| $V_{IH}$   | HIGH-level input voltage   |  | $0.7V_{CC2}$ | -    | 5.5  | V             |
| $V_{IL}$   | LOW-level input voltage  |  | -0.5         | -    | +1.2 | V             |
| $I_{LI}$   | input leakage current  | $V_I = 5.5\text{ V}$   | -            | -    | 10   | $\mu\text{A}$ |
| $I_{IL}$   | LOW-level input current  | $V_I = 0.2\text{ V}$   | -            | -    | 10   | $\mu\text{A}$ |
| $V_{OL}$   | LOW-level output voltage   | $I_{OL} = 6\text{ mA}$   | -            | 0.1  | 0.2  | V             |
| $C_{io}$   | input/output capacitance   | $V_I = 3\text{ V or }0\text{ V}; V_{DD} = 3.3\text{ V}$              | -            | -    | 7    | pF            |
|  |  | $V_I = 3\text{ V or }0\text{ V}; V_{DD} = 0\text{ V}$                | -            | 6    | 7    | pF            |
| $I_{trt(pu)}$  | transient boosted pull-up current  | $V_{CC2} = 4.5\text{ V};$<br>slew rate = $1.25\text{ V}/\mu\text{s}$ | -            | 6    | -    | mA            |

[1]  $V_{CC1}$  is the pull-up voltage for DDC source.

[2]  $I_{OL}$  between 100  $\mu\text{A}$  and 6 mA guaranteed by design (3 mA typical application)

[3]  $V_{CC2}$  is the pull-up voltage for DDC sink.

### 11. Package outline

HVQFN32: plastic thermal enhanced very thin quad flat package; no leads;  
32 terminals; body 5 x 5 x 0.85 mm

SOT617-3

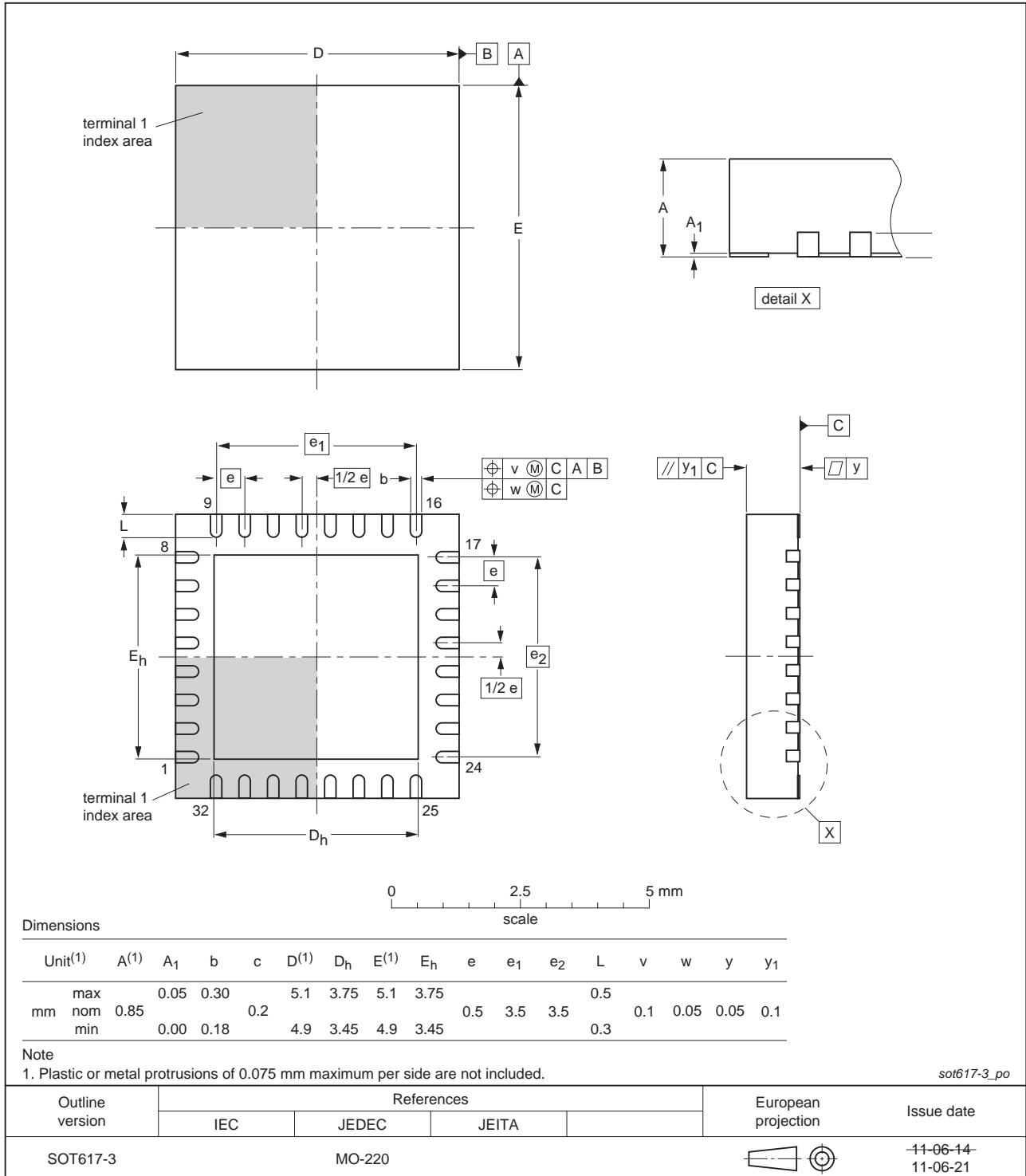


Fig 4. Package outline SOT617-3 (HVQFN32)

## 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 5](#)) 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 14](#) and [15](#)

**Table 14. SnPb eutectic process (from J-STD-020D)**

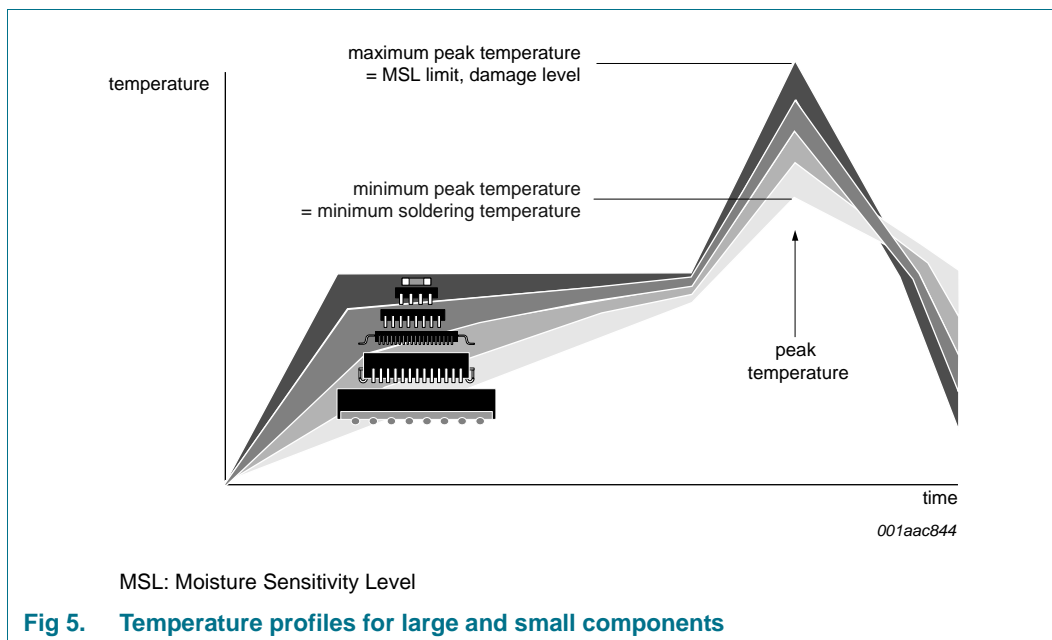
| Package thickness (mm) | Package reflow temperature (°C) |       |
|------------------------|---------------------------------|-------|
|                        | Volume (mm <sup>3</sup> )       |       |
|                        | < 350                           | ≥ 350 |
| < 2.5                  | 235                             | 220   |
| ≥ 2.5                  | 220                             | 220   |

**Table 15. Lead-free process (from J-STD-020D)**

| Package thickness (mm) | Package reflow temperature (°C) |             |        |
|------------------------|---------------------------------|-------------|--------|
|                        | Volume (mm <sup>3</sup> )       |             |        |
|                        | < 350                           | 350 to 2000 | > 2000 |
| < 1.6                  | 260                             | 260         | 260    |
| 1.6 to 2.5             | 260                             | 250         | 245    |
| > 2.5                  | 250                             | 245         | 245    |

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 5](#).



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

### 13. Abbreviations

Table 16. Abbreviations

| Acronym              | Description                                 |
|----------------------|---|
| CDM                  | Charged-Device Model                        |
| CEC                  | Consumer Electronics Control                |
| DDC                  | Data Display Channel                        |
| DVI                  | Digital Visual Interface                    |
| EMI                  | ElectroMagnetic Interference                |
| ESD                  | ElectroStatic Discharge                     |
| HBM                  | Human Body Model                            |
| HDMI                 | High-Definition Multimedia Interface        |
| HPD                  | Hot Plug Detect                             |
| I <sup>2</sup> C-bus | Inter-IC bus                                |
| I/O                  | Input/Output                                |
| NMOS                 | Negative-channel Metal-Oxide Semiconductor  |
| TMDS                 | Transition Minimized Differential Signaling |
| VESA                 | Video Electronic Standards Association      |

## 14. Revision history

Table 17. Revision history

| Document ID    | Release date                                 | Data sheet status  | Change notice | Supersedes  |
|----------------|--|--------------------|---------------|-------------|
| PTN3365 v.1.1  | 20150728                                     | Product data sheet | -             | PTN3365 v.1 |
| Modifications: | • Changed document status to Company Public. |                    |               |             |
| PTN3365 v.1    | 20141203                                     | Product data sheet | -             | -           |

## 15. Legal information

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| Document status <sup>[1][2]</sup> | Product status <sup>[3]</sup> | Definition  |
|-----------------------------------|-------------------------------|---|
| Objective [short] data sheet      | Development                   | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet    | Qualification                 | This document contains data from the preliminary specification.                       |
| Product [short] data sheet        | Production                    | This document contains the product specification.                                     |

[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".

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