# STUSB02E

## USB Transceiver

## General features

- Supports 1.5Mbps and 12Mbps serial data transmission

- ESD HBM: ±14kV on D+, D− Lines; ±5kV on VBUS

- ESD Compliant to IEC-61000-4.2 (Level 3)

- Separate I/O supply with operation down to 1.6V

- Integrated speed select termination supply

- Very low power consumption to meet USB 'suspend' current requirements

- Small QFN16 lead free package

- No power supply sequencing requirements

- Software controlled re-enumeration

## Description

The STUSB02E is a single chip USB transceiver that supports both full-speed (12Mbps) and low-speed (1.5Mbps) operation. It has an integrated 5V to 3.3V regulator which allows direct powering from the $V_{BUS}$. The transceiver has an integrated voltage detector to detect the presence of the $V_{BUS}$ voltage.

**QFN16 (3mmx3mm)**

The transceiver also supports Sharing mode when $V_{BUS}$ is not present, which allows the D+/D− lines to be shared with other serial protocols.

It is also designed to operate down to 1.6V so that it is compatible with lower system voltages of most portable systems, which include PDAs, MP3 Player and Cell phones.
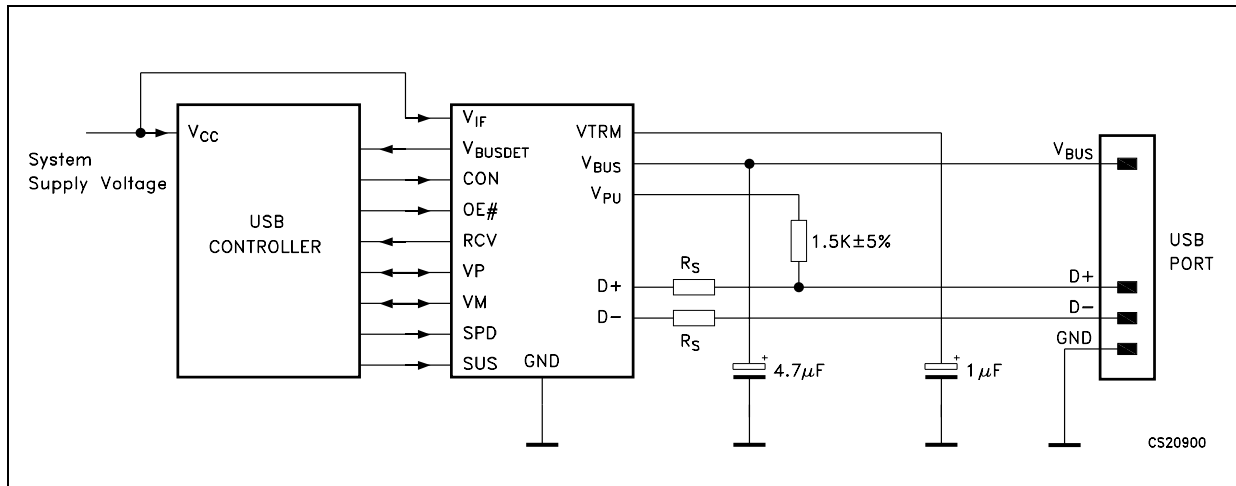
## Order code

| Part number | Package | Packaging |
|---|---|---|
| STUSB02EQR | QFN16 (3mm x 3mm) | 3000 parts per reel |

# Contents

# 1 Typical application

**Figure 1. Typical application**

# 2      Pin configuration

**Figure 2.     Pin connections (top view)**



**Table 1.      Pin description**

| PIN N° | SYMBOL | I/O | NAME AND FUNCTION |
|---|---|---|---|
| 0 | N.C. | | Not Connected. |
| 15 | $V_{IF}$ | I | System Interface Supply Voltage (1.6V to 3.6V). Provides reference supply voltage for system I/O interface signals. |
| 1 | SPD | I | Edge Rate Control. A logic HIGH operates at edge rates for "fullspeed" operation. A logic LOW operates edge rates for "lowspeed" operation. |
| 2 | RCV | O | Receive Data. Output for USB differential data. (see *Table 2*) |
| 3 | VP | I/O | If OE# = H, VP = Receiver output (+)<br>If OE# = L, VP = Driver input (+) (see *Table 2*) |
| 4 | VM | I/O | If OE# = H, VM = Receiver output (-)<br>If OE# = L, VM = Driver input (-) (see *Table 2*) |
| 5 | CON | I | CONNECT (input). Controls state of $V_{PU}$. Refer to $V_{PU}$ pin description for detail. |
| 6 | GND | | Ground Reference |
| 7 | SUS | I | Suspend (active-high). Turns off internal circuits to reduce supply current. |
| 9 | OE# | I | Output Enable (active-low). Enables transceiver data transmission onto the bus. When not active, the transceiver is in the receive mode. (see *Table 2*) |
| 10, 11 | D-, D+ | I/O | Differential data lines. (see *Table 2*) |
| 12 | VTRM | O | 3.3V Reference Supply Output. Requires a 1.0µF decoupling capacitor for stability. |
| 13 | $V_{PU}$ | O | Pull-up Supply Voltage Output. Used to connect 1.5kΩ pull-up speed detect resistor. If CON = 0, $V_{PU}$ is high impedance. If CON = 1, $V_{PU}$ = 3.3V ±10%. |
| 14 | $V_{BUS}$ | I | USB Bus Supply Voltage (4V to 5.5V). Supplies power to the USB transceiver and internal circuitry. |
| 8 | N.C. | | Not connected. |
| 16 | $V_{BUSDET}$ | O | $V_{BUS}$ indicator output. When $V_{BUS}$ > 2.9V, $V_{BUSDET}$ = High and when < 2.2V, $V_{BUSDET}$ = Low. |

# 3    Functional tables

**Table 2.    Function selection**

| SUS | OE# | D+, D- | RCV | VP/VM | Function |
|-----|-----|--------|-----|-------|----------|
| L | L | Driving | Active | Active | Normal transmit mode |
| L | H | Receiving | Active | Active | Normal receive mode |
| H | L | Hi-Z | L | Not Active | Low power state |
| H | H | Hi-Z | L | Active | Receiving during suspend (low power state) [1] |

(1) During suspend VP and VM are active in order to detect out of band signalling conditions

**Table 3.    Truth table during normal mode**

| OE# = L | | | | | |
|---------|--------|--------|--------|--------|--------|
| **Input** | | **Output** | | | **RESULT** |
| **VP** | **VM** | **D+** | **D-** | **RCV** | |
| L | L | L | L | X | SE0 |
| L | H | L | H | L | Logic Low |
| H | L | H | L | H | Logic High |
| H | H | X | X | X | Undefined |
| **OE# = H** | | | | | |
| **Input** | | **Output** | | | **Result** |
| **D+** | **D-** | **VP** | **VM** | **RCV** | |
| L | L | L | L | X | SE0 |
| L | H | L | H | L | Logic Low |
| H | L | H | L | H | Logic High |
| H | H | X | X | X | Undefined |

X = Undefined

# 4    Maximum ratings

**Table 4.    Absolute maximum ratings**

| Symbol | Parameter | Value | Unit |
|--------|-----------|-------|------|
| $V_{BUS}$ | Supply voltage | 6 | V |
| V+ | All other Inputs | -0.5 to 4.6 | V |
| $I_O$ | Output current (D+, D-) | $\pm 50$ | mA |
| $I_O$ | Output current (all others) | $\pm 15$ | mA |
| $I_I$ | Input current | $\pm 50$ | mA |
| ESD | D+, D-, HBM (Note 3) | $\pm 14$ | kV |
|  | $V_{BUS}$ (Note 3) | $\pm 5$ |  |
|  | All other pins (Note 3) | $\pm 2$ |  |
| $T_{STG}$ | Storage temperature range | -65 to + 150 | °C |
| $T_{OPR}$ | Operating temperature range | -40 to + 85 | °C |

Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional Operation under these conditions is not implied.

Note 3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k$\Omega$ in series with 100pF.

**Table 5.    Thermal data**

| Symbol | Parameter | Value | Unit |
|--------|-----------|-------|------|
| $R_{thJA}$ | Thermal resistance junction-ambient | 59 | °C/W |

# 5    Electrical characteristics

**Table 6.     DC electrical characteristics (System and USB interface)**
($V_{IF}$ = 3.6V, $V_{BUS}$ = 5V unless otherwise noted; $T_A$ = 25°C, specifications over temperature, -40 to 85°C)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{BUS}$ | USB Supply voltage | | 4 | | 5.5 | V |
| $V_{IF}$ | System I/F supply voltage | | 1.6 | | 3.6 | V |
| $V_{IL}$ | Low level input voltage (Note 4) | | | | $0.15V_{IF}$ | V |
| $V_{IH}$ | High level input voltage (Note 4) | | $0.85V_{IF}$ | | | V |
| $V_{OL}$ | Low level output voltage (Note 4) | $I_{OL}$ = 20µA | 0 | | 100 | mV |
| $V_{OH}$ | High level output voltage (Note 4) | $I_{OH}$ = -20µA | $V_{IF}$-100 | | $V_{IF}$ | mV |
| $I_{IL}$ | Input leakage current (Note 4) | | -5 | | 5 | µA |
| $I_{IF}$ | $V_{IF}$ Supply current (Note 7) | D+, D- are idle, OE# = SUS = 0 | | | 5 | µA |
| | | D+, D- are idle, OE# = SUS = 1 | | | 5 | |
| | | D+, D- active, $C_{LOAD}$ = 50pF, SPD = 1, f = 6MHz, (Note 5) | | | 650 | |
| | | D+, D- active, $C_{LOAD}$ = 600pF, SPD = 0, f = 750KHz, (Note 5) | | | 75 | |
| $I_{BUS}$ | $V_{BUS}$ Supply current | D+, D- are idle, $V_{BUS}$ = 5.25V Suspend Mode (SUS = 1), OE# = 1, SPD = 1 | | | 200 | µA |
| | | D+, D- are idle, $V_{BUS}$ = 5.25V SPD = 1, OE# = SUS = 0 | | | 5 | mA |
| | | D+, D- are idle, $V_{BUS}$ = 5.25V OE# = SUS = SPD = 0 | | | 700 | µA |
| | | D+, D- are idle, $V_{BUS}$ = 5.25V OE# = 1, SUS = SPD = 0 | | | 350 | |
| | | D+, D- active, $V_{BUS}$ = 5.25V $C_{LOAD}$ = 50pF, SPD = 1, f = 6 MHz OE# = SUS = 0 (Note 5) | | | 10 | mA |
| | | D+, D- active, $V_{BUS}$ = 5.25V $C_{LOAD}$ = 600pF, f = 750 KHz, OE# = SUS = SPD = 0 (Note 5) | | | 5 | |
| $I_{VPULEAK}$ | $V_{PU}$ Leakage current | CON = 0, $V_{PU}$ = 0V | -5 | | 5 | µA |
| $I_{VIFLEAK}$ | $V_{IF}$ Leakage current | $V_{IF}$ = 3.6V, $V_{BUS}$ = 0V | -5 | | 5 | µA |
| $V_{PU}$ | Pull-Up output voltage | $I_{TERM}$ = 200µA, $V_{BUS}$ = 4 to 5.25V | 3 | | 3.6 | V |
| $R_{SW}$ | $V_{PU}$ Internal switch resistance | $I_{TERM}$ = 10mA, $V_{BUS}$ = 4 to 5.25V | 7 | 9 | 11 | Ω |

Note 1. Exceeding the absolute maximum rating may damage the device.

Note 2. The device is not guaranteed to function outside its operating rating.

Note 3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.

Note 4. Specification applies to the following pins: SUS, SPD, RCV, CON, VP, VM, OE#, VBUSDET.

Note 5. Characterized specification(s), but not production tested.

Note 6. All AC parameters guaranteed by design but not production tested.

Note 7. RCV NOT LOADED

### Table 7. DC electrical characteristics (System and USB interface)

($V_{IF}$ = 3.6V, $V_{BUS}$ = 5V unless otherwise noted; $T_A$ = 25°C)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{BUS}$ | USB Supply voltage | | 4 | | 5.5 | V |
| $V_{IF}$ | System I/F supply voltage | | 1.6 | | 3.6 | V |
| $V_{IL}$ | Low level input voltage (Note 4) | | | | $0.15V_{IF}$ | V |
| $V_{IH}$ | High level input voltage (Note 4) | | $0.85V_{IF}$ | | | V |
| $V_{OL}$ | Low level output voltage (Note 4) | $I_{OL}$ = 20µA | | | 0.1 | V |
| $V_{OH}$ | High level output voltage (Note 4) | $I_{OH}$ = 20µA | $0.9V_{IF}$ | | | V |
| $I_{IL}$ | Input leakage current (Note 4) | | -5 | | 5 | µA |
| $I_{IF}$ | $V_{IF}$ Supply current (Note 7) | D+, D- are idle, OE# = SUS = 0 | | | 5 | µA |
| | | D+, D- active, $C_{LOAD}$ = 50pF, SPD = 1, f = 6MHz, (Note 5) | | 450 | | |
| | | D+, D- active, $C_{LOAD}$ = 50pF, SPD = 0, f = 750KHz, (Note 5) | | 50 | | |
| $I_{BUS}$ | $V_{BUS}$ Supply current | D+, D- are idle, $V_{BUS}$ = 5.25V Suspend Mode (SUS = 1) | | 70 | 150 | µA |
| | | D+, D- are idle, $V_{BUS}$ = 5.25V SPD = 1, OE# = SUS = 0 | | 3.0 | | mA |
| | | D+, D- are idle, $V_{BUS}$ = 5.25V OE# = SUS = SPD = 0 | | 300 | | µA |
| | | D+, D- are idle, $V_{BUS}$ = 5.25V OE# = 1, SUS = SPD = 0 | | 150 | | |
| | | D+, D- active, $V_{BUS}$ = 5.25V $C_{LOAD}$ = 50pF, SPD = 1, f = 6 MHz OE# = SUS = 0 (Note 5) | | 7.3 | | mA |
| | | D+, D- active, $V_{BUS}$ = 5.25V $C_{LOAD}$ = 600pF, f = 750 KHz, OE# = SUS = SPD = 0 (Note 5) | | 3.6 | | |
| $I_{VPULEAK}$ | $V_{PU}$ Leakage current | CON = 1, $V_{PU}$ = 0V | -5 | | 5 | µA |
| $I_{VIFLEAK}$ | $V_{IF}$ Leakage current | $V_{IF}$ = 3.6V, $V_{BUS}$ = 0V | -5 | | 5 | µA |
| $V_{PU}$ | Pull-Up output voltage | $I_{TERM}$ = 200µA, $V_{BUS}$ = 4 to 5.25V | | 3.3 | | V |
| $R_{SW}$ | $V_{PU}$ Internal switch resistance | $I_{TERM}$ = 10mA, $V_{BUS}$ = 4 to 5.25V | | 9 | | Ω |

Note 1. Exceeding the absolute maximum rating may damage the device.
Note 2. The device is not guaranteed to function outside its operating rating.
Note 3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.
Note 4. Specification applies to the following pins: SUS, SPD, RCV, CON, VP, VM, OE#, VBUSDET.
Note 5. Characterized specification(s), but not production tested.
Note 6. All AC parameters guaranteed by design but not production tested.
Note 7. RCV NOT LOADED

### Table 8. ESD Performance

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| ESD | IEC-1000-4-2 (D+, D-) | Air discharge (10 pulses) | | ± 8 | | kV |
| | | Contact discharge (10 pulses) | | ± 6 | | |
| | IEC-1000-4-2 ($V_{BUS}$ only) | Air discharge (10 pulses) | | ± 5 | | |
| | | Contact discharge (10 pulses) | | ± 5 | | |

**Table 9.    DC electrical characteristics (Transceiver)**
($V_{IF}$ = 3.6V, $V_{BUS}$ = 5V unless otherwise noted; $T_A$ = 25°C, specifications over temperature, -40 to 85°C)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|--------|-----------|-----------------|------|------|------|------|
| $I_{LO}$ | Hi-Z State data line leakage (suspend mode) | $V_I$ = 0 to 3.3 V, SUS = 1 | -10 | | 10 | μA |
| $V_{DI}$ | Differential input sensitivity | l(D+) - (D-)l | 0.2 | | | V |
| $V_{CM}$ | Differential common mode range | Includes $V_{DI}$ range | 0.8 | | 2.5 | V |
| $V_{SE}$ | Single ended receiver threshold | | 0.8 | | 2.0 | V |
| $V_{RHYS}$ | Receiver hysteresis | $V_{CM}$ = 0.8 V | | 100 | | mV |
| $V_{OL}$ | Static output low | $R_L$ = 1.5 KΩ at 3.6V (see test circuit) | | | 0.3 | V |
| $V_{OH}$ | Static output high | $R_L$ = 15 KΩ at GND (see test circuit) | 2.8 | | 3.6 | V |
| $C_I$ | Transceiver capacitance | Pin to GND | | 25 | | pF |
| $Z_{DRV}$ | Driver output resistance | Steady state drive | 9 | | 22 | Ω |

**Table 10.    DC electrical characteristics (Transceiver)**
($V_{IF}$ = 3.6V, $V_{BUS}$ = 5V unless otherwise noted; $T_A$ = 25°C)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|--------|-----------|-----------------|------|------|------|------|
| $I_{LO}$ | Hi-Z state data line leakage (suspend mode) | $V_I$ = 0 to 3.3 V, SUS = 1 | -2 | | 2 | μA |
| $V_{DI}$ | Differential input sensitivity | l(D+) - (D-)l | 0.2 | | | V |
| $V_{CM}$ | Differential common mode range | Includes $V_{DI}$ range | 0.8 | | 2.5 | V |
| $V_{SE}$ | Single ended receiver threshold | | 0.8 | | 2 | V |
| $V_{RHYS}$ | Receiver hysteresis | $V_{CM}$ = 0.8 V | | 50 | | mV |
| $V_{OL}$ | Static output low | $R_L$ = 1.5 KΩ at 3.6V (see *Test circuits*) | | | 0.3 | V |
| $V_{OH}$ | Static output high | $R_L$ = 15 KΩ at GND (see *Test circuits*) | 2.8 | | 3.6 | V |
| $C_I$ | Transceiver Capacitance [3] | Pin to GND | | 25 | | pF |
| $Z_{DRV}$ | Driver Output Resistance | Steady state drive | | 16 | | Ω |

(3) Pins D+, D-

### Table 11. AC electrical characteristics

($V_{IF}$ = 3.6V, $V_{BUS}$ = 5V unless otherwise noted; $T_A$ = 25°C.) (Note 6)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $T_R$ | Transition Rise Time (LOW SPEED) | $C_L$ = 50pF (*Figure 4*) | 75 | | | ns |
| | | $C_L$ = 600pF | | | 300 | |
| $T_F$ | Transition Fall Time (LOW SPEED) | $C_L$ = 50pF (*Figure 4*) | 75 | | | ns |
| | | $C_L$ = 600pF | | | 300 | |
| $T_R, T_F$ | Rise/Fall Time Matching (LOW SPEED) | ($T_R, T_F$) | 80 | | 125 | % |
| $V_{CRS}$ | Output Signal Crossover Voltage (LOW SPEED) | | 1.3 | | 2 | V |
| $T_R$ | Transition Rise Time (FULL SPEED) | $C_L$ = 50pF (*Figure 4*) | 4 | | 20 | ns |
| $T_F$ | Transition Fall Time (FULL SPEED) | $C_L$ = 50pF (*Figure 4*) | 4 | | 20 | ns |
| $T_R, T_F$ | Rise/Fall Time Matching (FULL SPEED) | ($T_R, T_F$) | 90 | | 111.11 | % |
| $V_{CRS}$ | Output Signal Crossover Voltage (FULL SPEED) | | 1.3 | | 2 | V |
| $t_{PVZ}$ | OE# TO RCVR Tri-State Delay | *Figure 3* | | 3 | | ns |
| $t_{PZD}$ | Receiver Tri-State to Transmit Delay | LOW SPEED (*Figure 3*) | 13 | | | ns |
| | | FULL SPEED (*Figure 3*) | 32 | | | |
| $t_{PDZ}$ | OE# TO RCVR Tri-State Delay | *Figure 3* | | 6 | | ns |
| $t_{PZV}$ | Driver Tri-State to Receive Delay | *Figure 3* | | 27 | | ns |
| $t_{PLH} t_{PHL}$ | VP, VM to D+, D- Propagation Delay | *Figure 6* | | 16 | 20 | ns |
| $t_{PLH} t_{PHL}$ | D+, D- to RCV Propagation Delay | *Figure 5* | | 13 | 20 | ns |
| $t_{PLH} t_{PHL}$ | D+, D- to VP, VM Propagation Delay | *Figure 5* | | 8 | 20 | ns |

Note 1. Exceeding the absolute maximum rating may damage the device.

Note 2. The device is not guaranteed to function outside its operating rating.

Note 3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.

Note 4. Specification applies to the following pins: SUS, SPD, RCV, CON, RCV, VP, VM, OE#.

Note 5. Characterized specification(s), but not production tested.

Note 6. All AC parameters guaranteed by design but not production tested.

# 6 Timing diagram

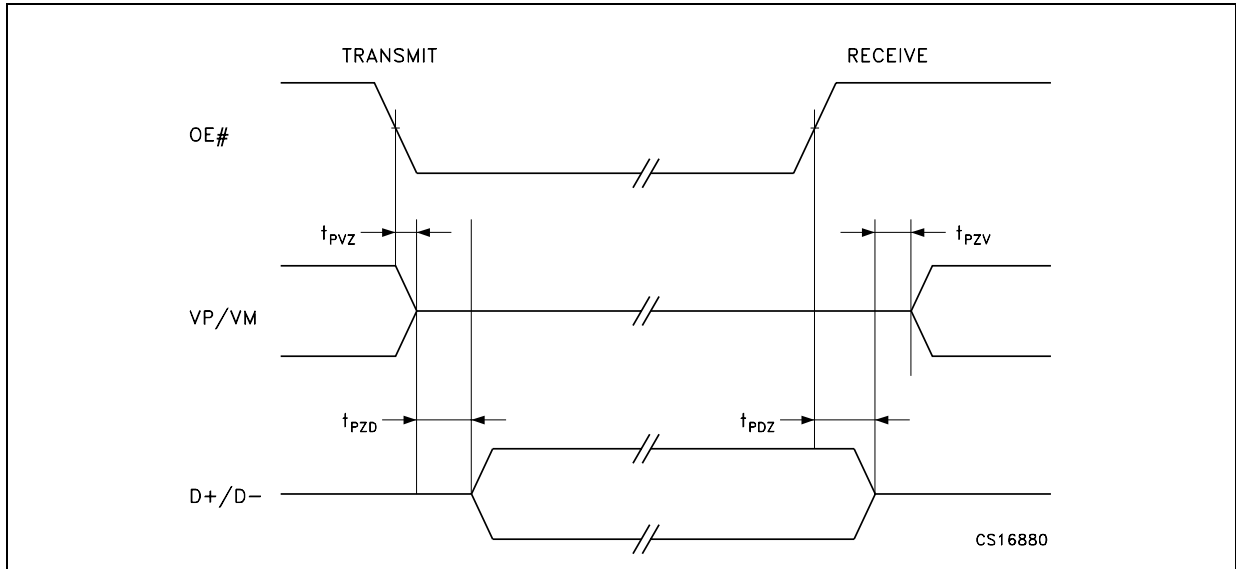**Figure 3.    Enable and disable times**
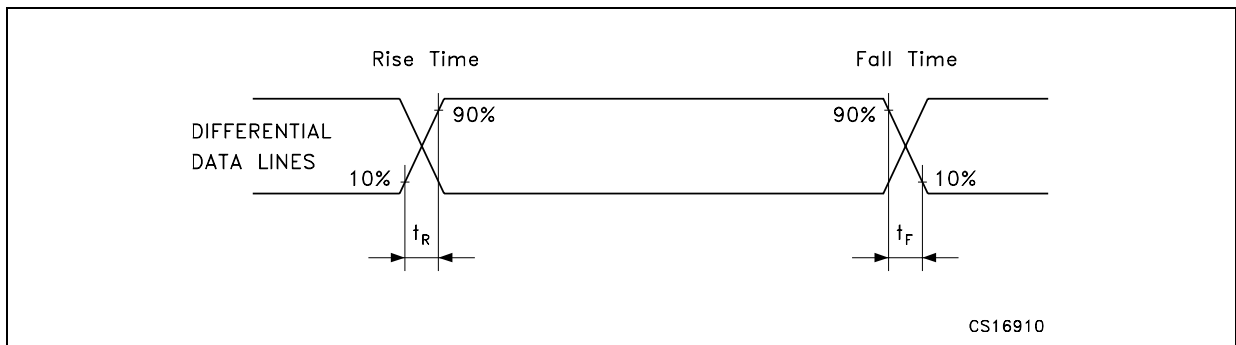


**Figure 4.    Rise and fall times**

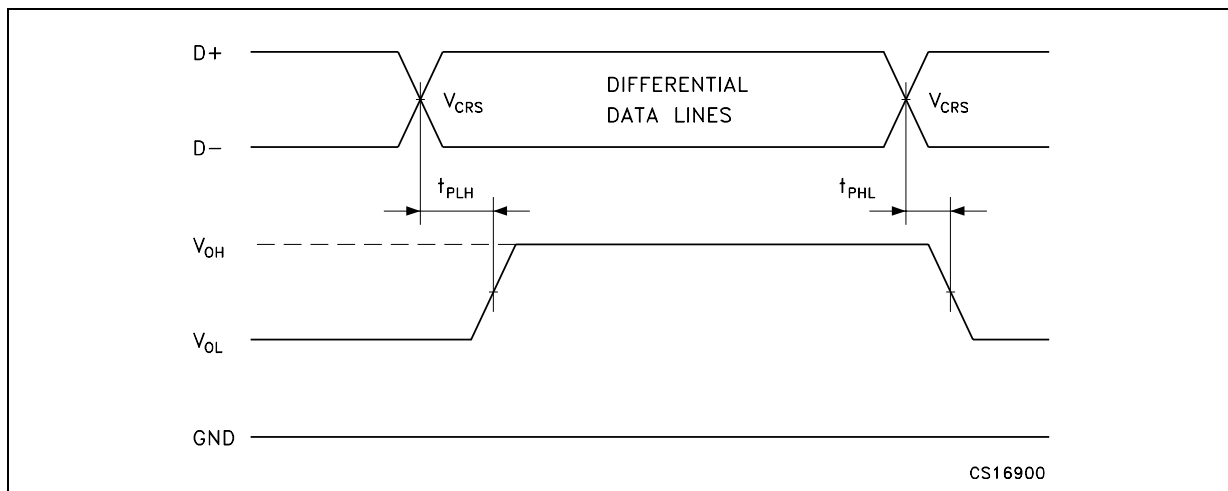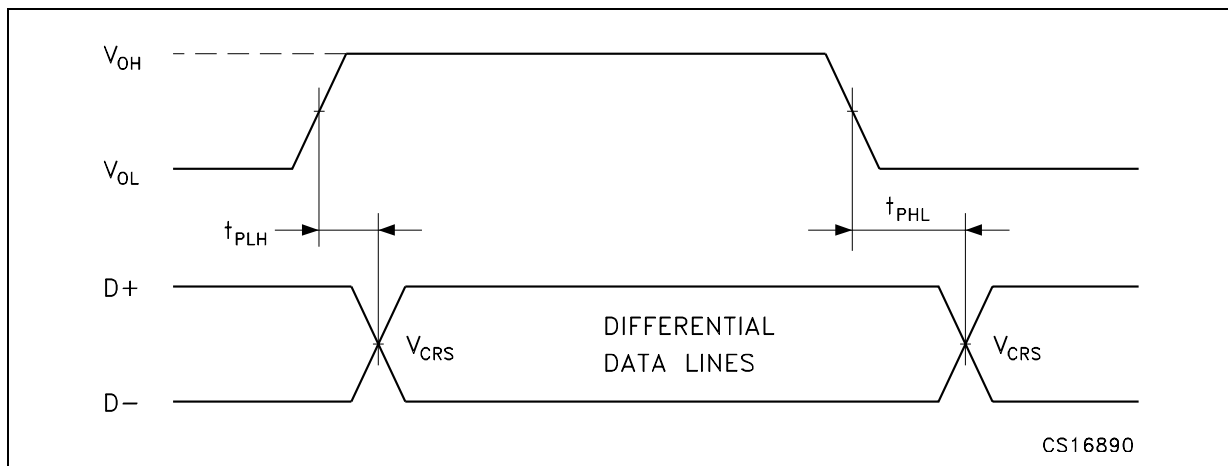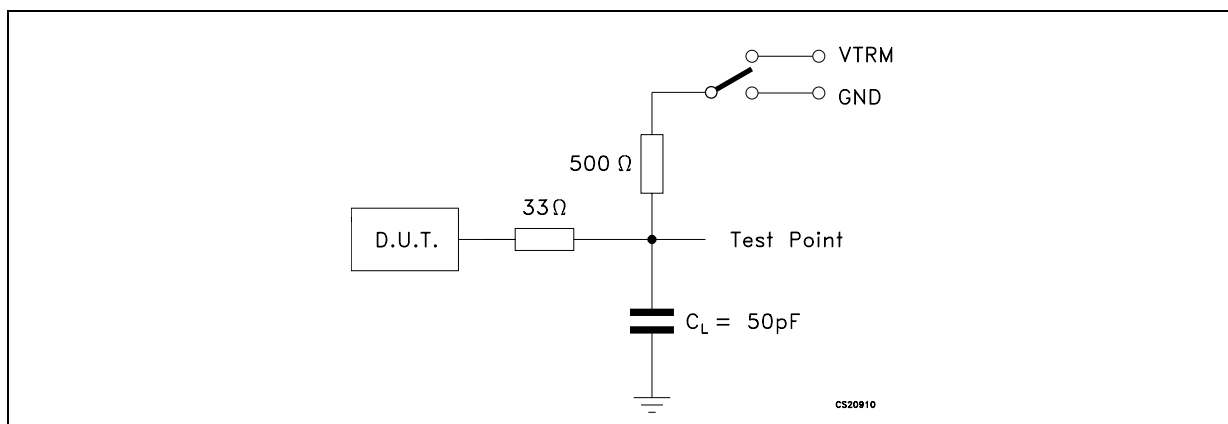**Figure 5.    Receiver propagation delay**



**Figure 6.    Driver propagation delay ($C_L$ = 50pF)**



Minimum Timing LS and maximum timing FS

**Figure 7.    Enable and disable time circuit**



Switch = GND for $t_{PZH}$ and $t_{PHZ}$; V = VTRM for $t_{PZL}$ and $t_{PLZ}$

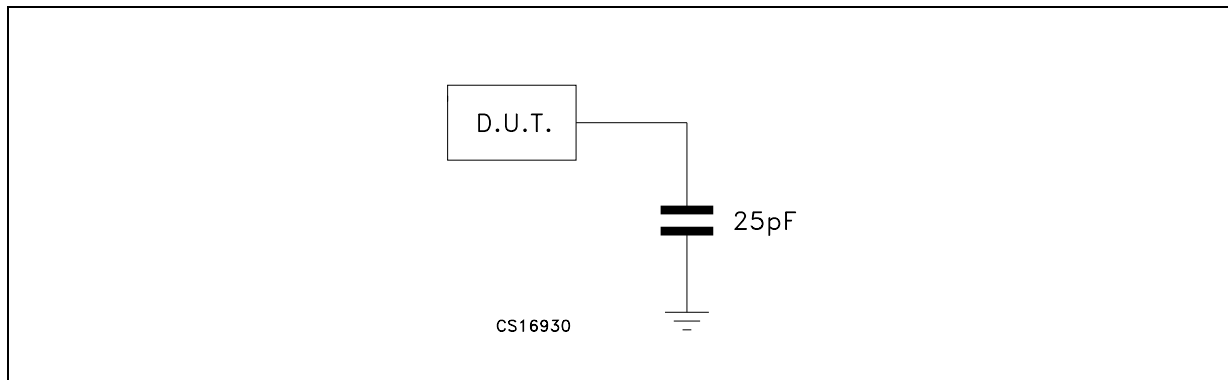# 7    Test circuits

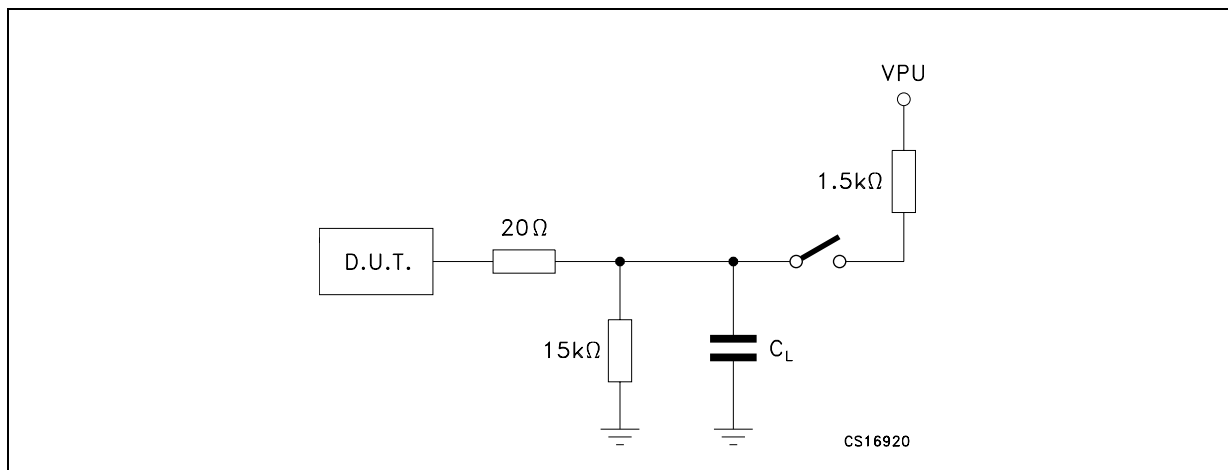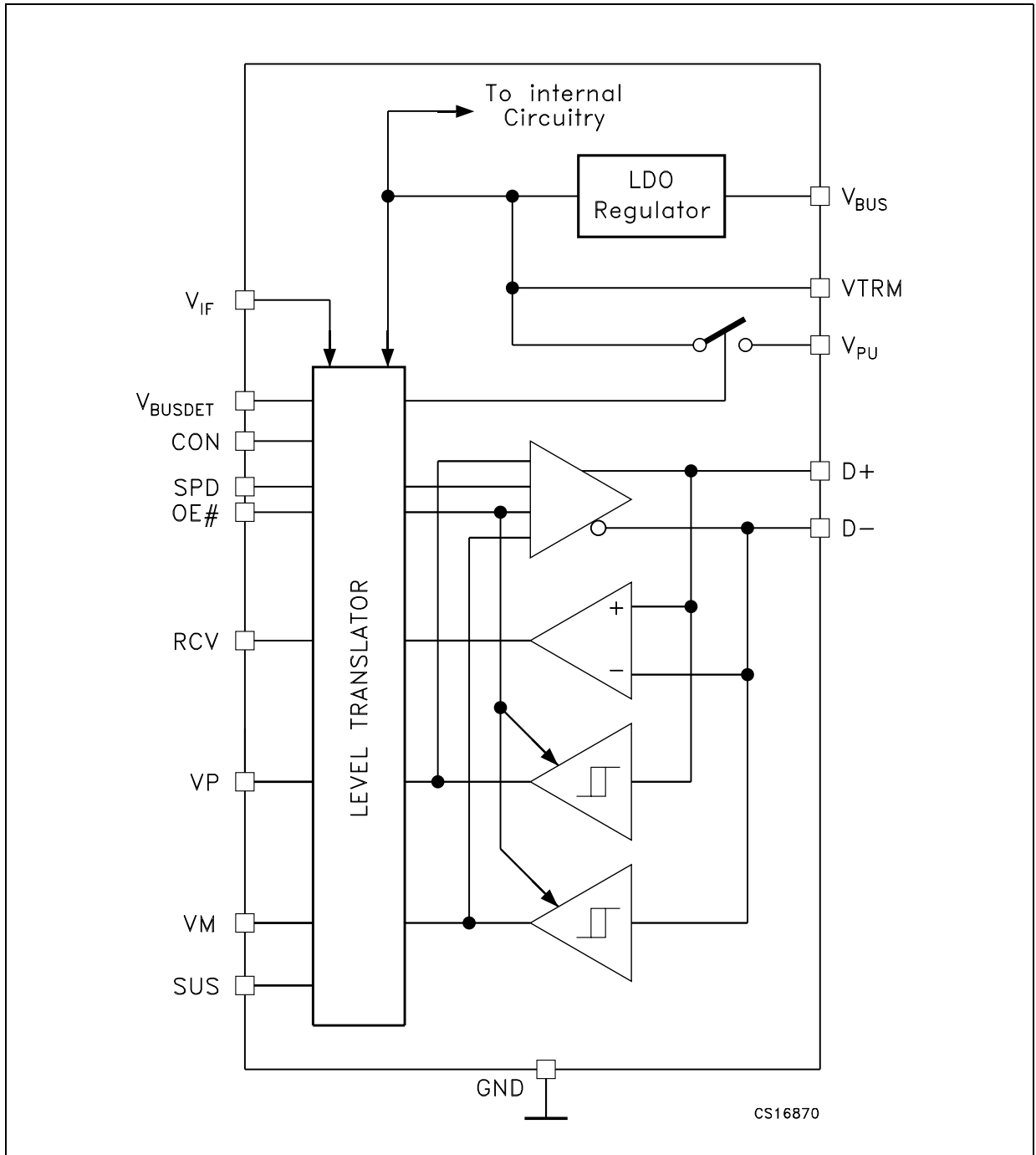**Figure 8.    Load for VP, VM, RCV**



**Figure 9.    Load for D+, D-**

**Figure 10. Functional diagram**

# 8 Functional description

The STUSB02E is designed to provide USB connectivity in mobile systems where available system supply voltages are not able to satisfy USB requirements. The STUSB02E can operate down to supply voltages of 1.6V. As shown in the circuit above, the STUSB02E takes advantage of the USB supply voltage, $V_{BUS}$, to operate the transceiver. The system voltage, $V_{IF}$, is used to set the reference voltage used by the digital I/O lines interfacing to the system controller. Internal circuitry provides translation between the USB and system voltage domains. $V_{IF}$ will typically be the main supply voltage rail for the controller.

In addition, a 3.3V, 10% termination supply voltage, $V_{PU}$, is provided to support speed selection. $V_{PU}$ can be disabled or enabled under software control via the CON input. This allows for software-controlled connect or disconnect states. A 1.5K$\Omega$ resistor is required to be connected between this pin and the D+ or D– lines to respectively specify full speed or low speed operation.
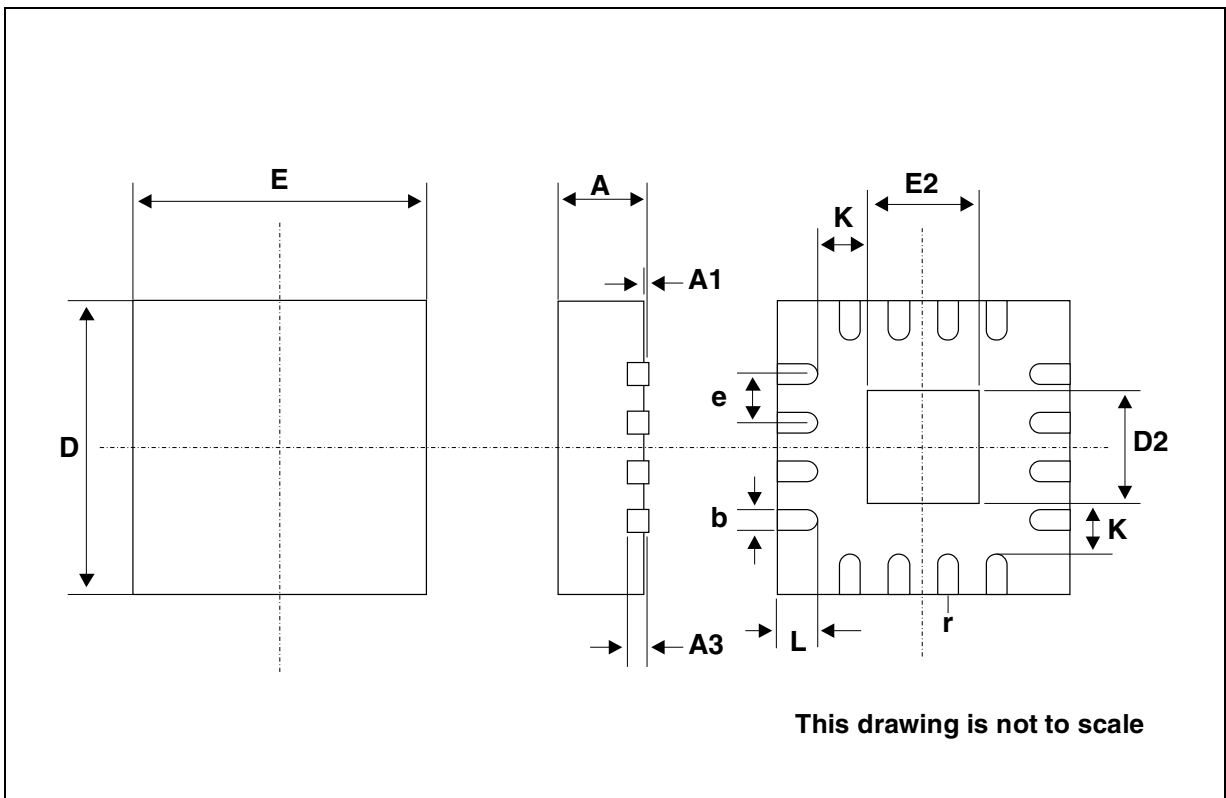
The use of ESD transient protection devices is not required for operation, but is recommended.

# 9    Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.
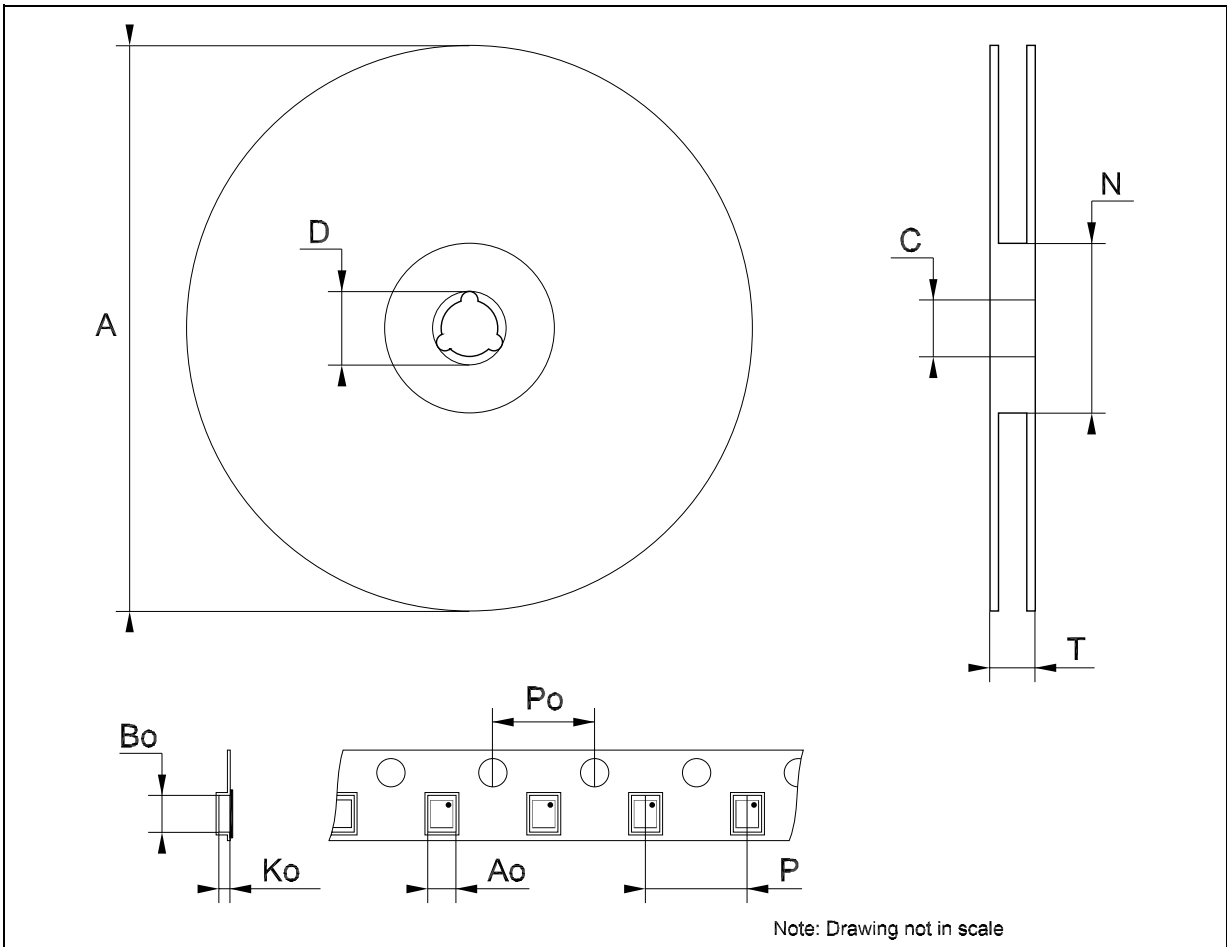
## QFN16 (3mmx3mm) MECHANICAL DATA

| DIM. | mm. | | | inch | | |
|------|------|-----|------|------|------|------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | 0.80 | 0.90 | 1.00 | 0.032 | 0.035 | 0.039 |
| A1 | | 0.02 | 0.05 | | 0.001 | 0.002 |
| A3 | | 0.20 | | | 0.008 | |
| b | 0.18 | 0.25 | 0.30 | 0.007 | 0.010 | 0.012 |
| D | | 3.00 | | | 0.118 | |
| D2 | 1.55 | 1.70 | 1.80 | 0.061 | 0.067 | 0.071 |
| E | | 3.00 | | | 0.118 | |
| E2 | 1.55 | 1.70 | 1.80 | 0.061 | 0.067 | 0.071 |
| e | | 0.50 | | | 0.020 | |
| K | | 0.20 | | | 0.008 | |
| L | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |
| r | 0.09 | | | 0.006 | | |



**This drawing is not to scale**

## Tape & Reel QFNxx/DFNxx (3x3) MECHANICAL DATA

| DIM. | mm. | | | inch | | |
|------|-----|-----|------|------|------|------|
|      | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A    |      |     | 330  |      |      | 12.992 |
| C    | 12.8 |     | 13.2 | 0.504 |     | 0.519 |
| D    | 20.2 |     |      | 0.795 |     |      |
| N    | 60   |     |      | 2.362 |     |      |
| T    |      |     | 18.4 |      |      | 0.724 |
| Ao   |      | 3.3 |      |      | 0.130 |      |
| Bo   |      | 3.3 |      |      | 0.130 |      |
| Ko   |      | 1.1 |      |      | 0.043 |      |
| Po   |      | 4   |      |      | 0.157 |      |
| P    |      | 8   |      |      | 0.315 |      |



Note: Drawing not in scale

# 10 Revision history

**Table 12. Revision history**

| Date | Revision | Changes |
|------|----------|---------|
| 19-Oct-2005 | 1 | First Release. |
| 21-Feb-2006 | 2 | Declaration of conformity with USB 2.0 specification removed. |
| 07-Apr-2006 | 3 | Corrected wrong links to figures in table 11. |
| 14-Mar-2007 | 4 | Update tape & reel. |

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