**±15kV ESD Protected, 10Mbps, Full Fail-safe, RS-485 Transceivers**
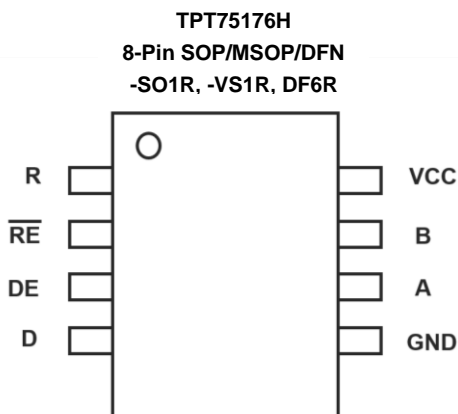
## Features

- **High Data Rates: 10Mbps At 5V Supply**
- **30/50ns (Max) Tx/Rx Propagation Delays; 6ns (Max) Skew**
- **Full Fail-safe (Open, Short, Terminated) Receivers**
- **Up to 256 Nodes on a Bus (1/8 unit load)**
- **Wide Supply Voltage 3V to 5.5V**
- **Low Quiescent Supply Current: 1.65 mA**
- **Bus-Pin Protection:**
  - **±15 kV HBM protection**
  - **±15 kV IEC-ESD**
- **Pb-Free**

## Applications

- PROFIBUS® DP and FMS Networks
- SCSI "Fast 40" Drivers and Receivers
- Motor Controller/Position Encoder Systems
- Factory Automation
- Field Bus Networks
- Industrial/Process Control Networks

## Description

3PEAK's TPT75176H is enhanced RS485 which exceeds standard TIA/EIA-485-A with ±15kV IEC-ESD Protected, 3V~5.5V powered, single transceiver for balanced communication. It also features the larger output voltage and higher data rate - up to 10Mbps - required by high speed PROFIBUS applications, and is offered in Industrial and Extended Industrial (-40°C to +125°C) temperature ranges.
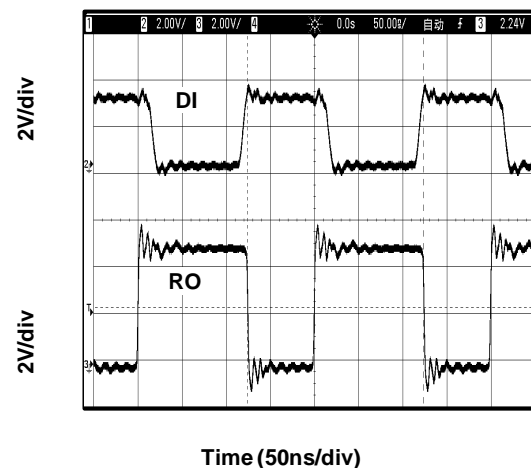
This transceiver requires a 3V~5.5V tolerance supply, and delivers at least a 2.1V differential output voltage on 5V supply condition. This translates into better noise immunity (data integrity), longer reach, or the ability to drive up to three 120Ω terminations in "star" or other non-standard bus topologies, at the exceptional 10Mbps data rate.

Receiver (Rx) inputs feature a "Full Fail-Safe" design, which ensures a logic high Rx output if Rx inputs are floating, shorted, or terminated but undriven. Rx outputs feature high drive levels (typically >25mA @ $V_{OL}$ = 1V) to ease the design of optically isolated interfaces.

The TPT75176H is available in an SOP8, MSOP8 and DFN3X3-8L package, and is characterized from –40°C to 125°C.

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## Pin Configuration (Top View)

**TPT75176H**
**8-Pin SOP/MSOP/DFN**
**-SO1R, -VS1R, DF6R**



**Loopback Test At 10Mbps/5V**



**Time (50ns/div)**

## Revision History

| Date | Revision | Notes |
|------|----------|-------|
| 2019/2/22 | Rev. Pre 0.1 | Definition Version 0 |
| 2019/3/25 | Rev. Pre 0.2 | Update package information |
| 2019/4/19 | Rev. Pre 0.3 | Update tape and reel information |
| 2019/7/29 | Rev. Pre 0.4 | Update ESD level |
| 2019/9/20 | Rev. 0 | Final version, update full temp data |
| 2020/3/18 | Rev. A | Update Receiver rise/fall time and add the note1 for Absolute Maximum Ratings |
| | | |

## Order Information

| Model Name | Order Number | Package | Transport Media, Quantity | Marking Information |
|------------|--------------|---------|---------------------------|---------------------|
| TPT75176H | TPT75176HL1-SO1R | 8-Pin SOP | Tape and Reel, 4,000 | T176H |
| TPT75176H | TPT75176H-VS1R | 8-Pin MSOP | Tape and Reel, 3,000 | 176H |
| TPT75176H | TPT75176HL1-DF6R | 8-Pin DFN | Tape and Reel, 4,000 | 176H |

## Functional Table

**DRIVER PIN FUNCTIONS**

| INPUT | ENABLE | OUTPUTS | | DESCRIPTION |
|---|---|---|---|---|
| D | DE | A | B | |
| NORMAL MODE | | | | |
| H | H | H | L | Actively drives bus High |
| L | H | L | H | Actively drives bus Low |
| X | L | Z | Z | Driver disabled |
| X | OPEN | Z | Z | Driver disabled by default |
| OPEN | H | H | L | Actively drives bus High |

**RECEIVER PIN FUNCTIONS**

| DIFFERENTIAL INPUT | ENABLE | OUTPUT | DESCRIPTION |
|---|---|---|---|
| $V_{ID} = V_A - V_B$ | /RE | R | |
| NORMAL MODE | | | |
| $V_{IT+} < V_{ID}$ | L | H | Receive valid bus High |
| $V_{IT-} < V_{ID} < V_{IT+}$ | L | ? | Indeterminate bus state |
| $V_{ID} < V_{IT-}$ | L | L | Receive valid bus Low |
| X | H | Z | Receiver disabled |
| X | OPEN | Z | Receiver disabled |
| Open, short, idle Bus | L | H | Indeterminate bus state |

## Absolute Maximum Ratings

$V_{DD}$ to GND.................................................................................................................-0.3V to +7V

Input Voltages D, DE, RE………………………………………………………………………...-0.3V to (VCC + 0.3V)

Input/Output Voltages A, B………………………………………………………………..…………………… -15V to +15V

A, B (Transient Pulse Through 100Ω, Note 1)……………………………………………….…….…..…… ±100V

R…………………………………………………………………………………………………… -0.3V to (VCC +0.3V)

Short Circuit Duration A, B……………………………………………………………………………….Continuous

ESD Rating…………………………………………………………………………………….. See Specification Table

## Recommended Operating Conditions

Supply Voltage………………………………………………………………………….……………3V~5.5V

Temperature Range……………………………………………………………………….…-40°C to +125°C

Bus Pin Common Mode Voltage Range …………………………………………………..…… -7V to +12V

Thermal Resistance, Θ$_{JA}$ (Typical) 8-Pin SOP Package …………………………………..……152°C/W

8-Pin MSOP Package ……………………………………………………….……………….…..…..……… 200°C/W

Maximum Junction Temperature (Plastic Package) ……………………………………..……….……+150°C

Maximum Storage Temperature Range ……………………………………………….………………… -65°C to +150°C

**Note 1:** Tested according to TIA/EIA-485-A, Section 4.2.6 (±100V for 15μs at a 1% duty cycle).

## Electrical Characteristics

Test Conditions: $V_{CC}$ = 5V, Ta = -45 ~ +125°C (unless otherwise noted)

| Parameter | | Conditions | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| $|V_{OD}|$ | Driver differential-output voltage magnitude | RL = 60 Ω with VA or VB from –7 to +12 V, VCC = 4.5V~5.5V | See Figure 1B | 2.1 | 2.8 | | V |
| | | RL = 60 Ω with VA or VB from –7 to +12 V, VCC = 3.0~3.6V | | 1.5 | 2.0 | | |
| | | RL = 54 Ω, VCC = 5V | See Figure 1A | 2.1 | 2.8 | | V |
| | | RL = 54 Ω, VCC = 3V | | 1.5 | 1.9 | | |
| | | RL = 100 Ω, VCC = 5V | | 2.1 | 3.5 | | |
| | | RL = 100 Ω, VCC = 3V | | 1.5 | 2.3 | | |
| $\triangle|V_{OD}|$ | Change in magnitude of driver differential-output voltage | RL = 54 Ω, CL=50 pF, VCC = 5V | See Figure 1A | -50 | 1 | 50 | mV |
| $V_{OC(SS)}$ | Steady-stage common-mode output voltage | Center of two 27 Ω load resistors | See Figure 1A | 1 | $V_{CC}/2$ | 3 | V |
| $\triangle V_{OC}$ | Change in differential driver common-mode output voltage | | | | 50 | | mV |
| $V_{OC(PP)}$ | Peak-to-peak driver common-mode output voltage | | | | 500 | | |
| $C_{OD}$ | Differential output capacitance | | | | 8 | | pF |
| $V_{IT+}$ | Positive-going receiver differential-input voltage threshold | $V_A$ or $V_B$ from –7 to +12 V | | | -90 | -40 | mV |
| $V_{IT-}$ | Negative-going receiver differential-input voltage threshold | $V_A$ or $V_B$ from –7 to +12 V | | -220 | -155 | | mV |
| $V_{HYS}$ | Receiver differential-input voltage threshold hysteresis ($V_{IT+} - V_{IT-}$ ) | | | | 70 | | mV |
| $V_{IH}$ | Logic Input High Voltage | DI, DE, $\overline{RE}$ | | 2 | | | V |
| $V_{IL}$ | Logic Input Low Voltage | DI, DE, $\overline{RE}$ | | | | 0.8 | V |
| $V_{OH}$ | Receiver high-level output voltage | $I_{OH}$= -8 mA | | 3 | 4.5 | | V |
| $V_{OL}$ | Receiver low-level output voltage | $I_{OL}$= 8 mA | | | | 0.4 | V |
| $I_I$ | Driver input, driver enable and | DI, DE, $\overline{RE}$ | | -5 | | 5 | µA |
| $I_{OZ}$ | Receiver high-Z output current | $V_O$ = 0 V or $V_{CC}$, /RE at $V_{CC}$ | | -1 | | 1 | µA |
| $|I_{OS}|$ | Driver short-circuit output current | │IOS│ with $V_A$ or $V_B$ from –7 to +12 V | | -250 | 120 | 250 | mA |
| | | Bus pin A,B short current | | | | 150 | mA |
| $I_{IN}$ | Bus input current(driver disabled) | $V_{CC}$ = 4.5 to 5.5 V or $V_{CC}$ = 0 V, DE at 0 V | VI= 12 V | | | 120 | uA |
| | | | VI= -7 V | -110 | | | |
| $I_{CC}$ | Supply current(quiescent) | Driver and receiver enabled | DE = $V_{CC}$, /RE = GND, No LOAD | | 1.9 | 2.2 | mA |
| | | Driver enabled, receiver disabled | DE = $V_{CC}$, /RE = $V_{CC}$, No LOAD | | 1.8 | 2.2 | |
| | | Driver disabled, receiver enabled | DE = GND, /RE = GND, No LOAD | | 1.7 | 2.0 | |
| | | Driver and receiver disabled | DE = GND, /RE = $V_{CC}$, D= $V_{cc}$ No LOAD | | 1.65 | 2.0 | |

## Switching Characteristics

| PARAMETER | | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DRIVER** | | | | | | | |
| $f_{MAX}$ | Maximum Data Rate | $V_{OD} \geq \pm1.5V$, $R_L = 54\Omega$, $C_L = 100pF$ (Figure 4) | | | | 10 | Mbps |
| $t_r$, $t_f$ | Driver differential-output rise and fall times | $R_L = 54 \Omega$, $C_L=50pF$ | See Figure 2 | | 8 | | ns |
| $t_{PHL}$, $t_{PLH}$ | Driver propagation delay | | | | 21 | 30 | |
| $t_{SK(P)}$ | Driver pulse skew, $\lvert t_{PHL} - t_{PLH}\rvert$ | | | | 3 | 6 | |
| $t_{PHZ}$, $t_{PLZ}$ | Driver disable time | | See Figure 3 | | 30 | 50 | ns |
| $t_{PZH}$, $t_{PZL}$ | Driver enable time | Receiver enabled | | | 20 | 45 | |
| | Driver enable time | Receiver disabled | | | 30 | 50 | ns |
| **RECEIVER** | | | | | | | |
| $t_r$, $t_f$ | Receiver output rise and fall times | $C_L=15$ pF | See Figure 5 | | 4 | | ns |
| $t_{PHL}$, $t_{PLH}$ | Receiver propagation delay time | | | | 35 | 50 | |
| $t_{SK(P)}$ | Receiver pulse skew, $\lvert t_{PHL} - t_{PLH}\rvert$ | | | | 10 | 15 | |
| $t_{PHZ}$, $t_{PLZ}$ | Receiver disable time | | | | 30 | 60 | ns |
| $t_{PZH}$, $t_{PZL}$ | Receiver enable time | Driver enabled | | | 20 | 30 | ns |
| | Receiver enable time | Driver disabled | | | 25 | 40 | ns |
| **ESD** | | | | | | | |
| Human Body Model, per ANSI/ESDA/JEDEC JS-001 / ANSI/ESD STM5.5.1 | | RS-485 Pins (A, B) | | | ±15 | | kV |
| | | All Other Pins | | | ±4 | | kV |
| CDM, per ANSI/ESDA/JEDEC JS-002 | | RS-485 | | | ±1.5 | | kV |
| IEC-61000-4-2, IEC-Contact ESD,   Bus Pins | | RS-485 Pins (A, B) | | | ±15 | | kV |

## Test Circuits and Waveforms
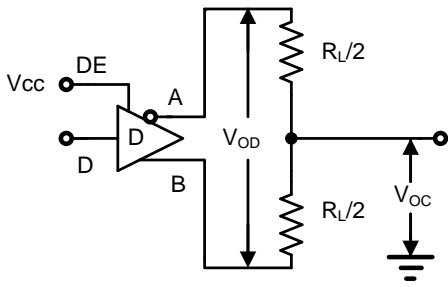


Figure 1A. V$_{OD}$ and V$_{OC}$
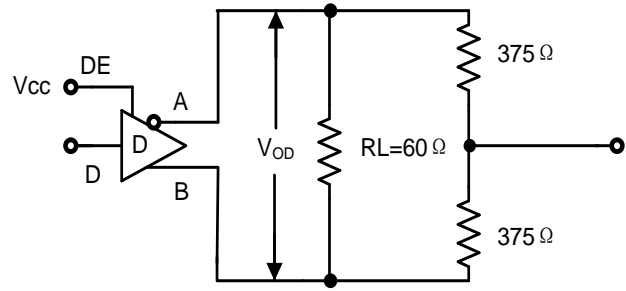
Figure 1B. V$_{OD}$ with Common Mode Load

Figure 1. DC Driver Test Circuits
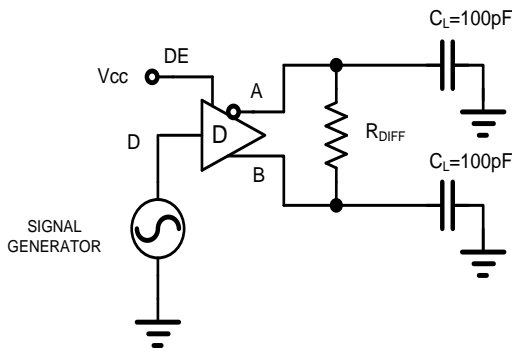


Figure 2A. Test Circuit
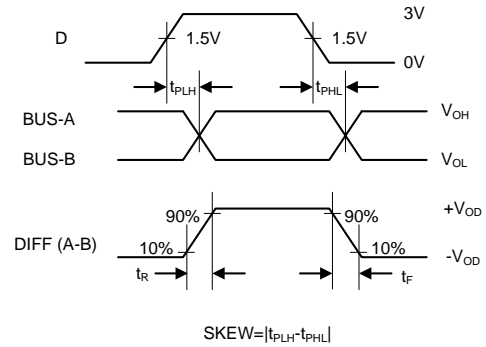
Figure 2B. Measurement Points

SKEW=|t$_{PLH}$-t$_{PHL}$|

Figure 2. Driver Propagation Delay and Differential Transition Times
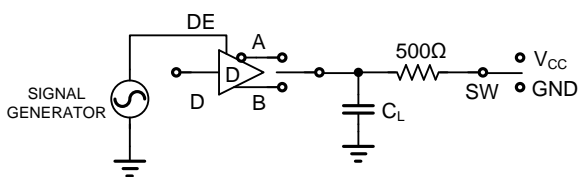


| PARAMETER | OUTPUT | RE | DI | SW | CL (pF) |
|-----------|--------|----|----|----|---------|
| tPHZ | A/B | X | 1/0 | GND | 15 |
| tPLZ | A/B | X | 0/1 | VCC | 15 |
| tPZH | A/B | 0 | 1/0 | GND | 100 |
| tPZL | A/B | 0 | 0/1 | VCC | 100 |
| tPZH(SHDN) | A/B | 1 | 1/0 | GND | 100 |
| tPZL(SHDN) | A/B | 1 | 0/1 | VCC | 100 |

Figure 3A. Test Circuit
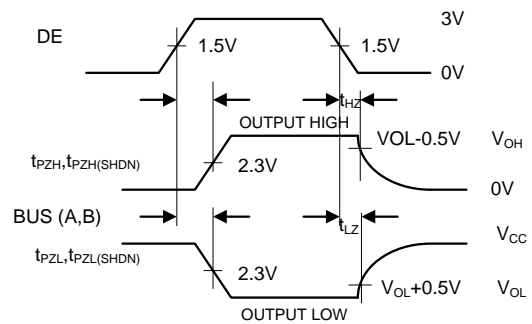
Figure 3B. Measurement Points

Figure 3. Driver Enable and Disable Times

## Test Circuits and Waveforms (continue)
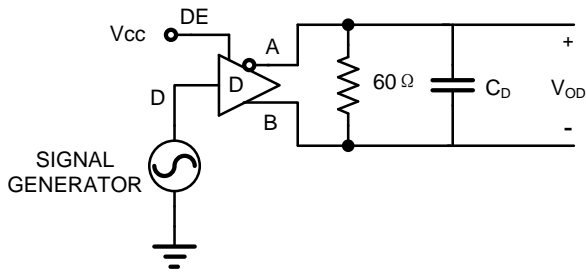
Figure 4A. Test Circuit
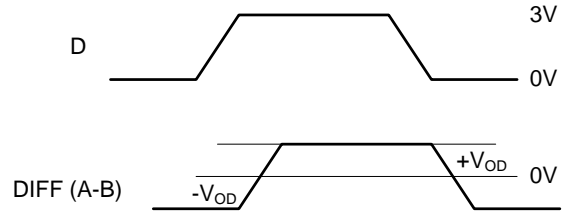
Figure 4B. Measurement Points

Figure 4. Driver Data rate
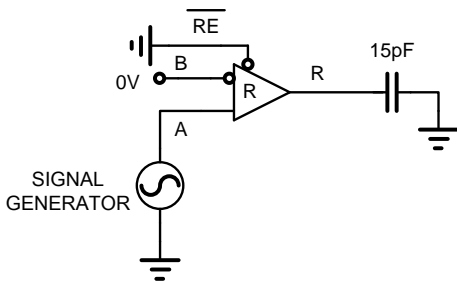
Figure 5A. Test Circuit
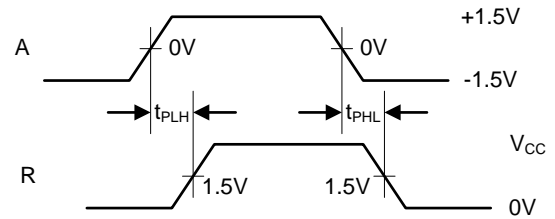
Figure 5B. Measurement Points

Figure 5. Receiver Propagation Delay and Data rate
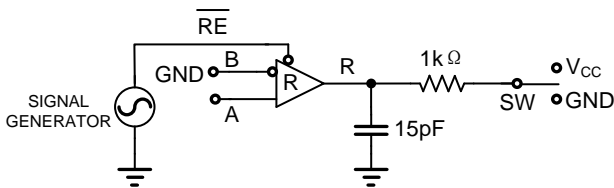
| PARAMETER | DE | A | SW |
|---|---|---|---|
| tPHZ | 1 | +1.5V | GND |
| tPLZ | 1 | -1.5V | VCC |
| tPZH | 1 | +1.5V | GND |
| tPZL | 1 | -1.5V | VCC |
| tPZH(SHDN) | 0 | +1.5V | GND |
| tPZL(SHDN) | 0 | -1.5V | VCC |

Figure 6A. Test Circuit
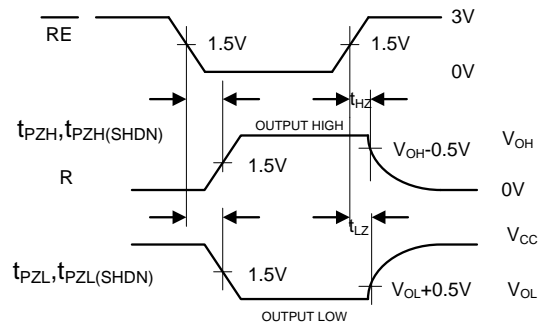
Figure 6B. Measurement Points

Figure 6. Receiver Enable and Disable Times

## Detailed Description

**High Data Rate**

RS-485/RS-422 are intended for network lengths up to 4000', but the maximum system data rate decreases as the transmission length increases. Devices operating at 10Mbps are limited to lengths less than 100'.

Twisted pair is the cable of choice for RS-485/RS-422 networks. Twisted pair cables tend to pick up noise and other electromagnetically induced voltages as common mode signals, which are effectively rejected by the differential receiver in this IC.

Proper termination is imperative to minimize reflections. In point-to-point, or point-to-multipoint (single driver on bus) networks, the main cable should be terminated in its characteristic impedance (typically 120Ω) at the end farthest from the driver. In multi-receiver applications, stubs connecting receivers to the main cable should be kept as short as possible. Multipoint (multi-driver) systems require that the main cable be terminated in its characteristic impedance at both ends. Stubs connecting a transceiver to the main cable should be kept as short as possible.

The TPT75176H may also be used at slower data rates over longer cables, but there are some limitations. The Rx is optimized for high speed operation, so its output may glitch if the Rx input differential transition times are too slow. Keeping the transition times below 500ns, which equates to the Tx driving a 1000' (305m) CAT 5 cable, yields excellent performance over the full operating temperature range. For below test waveform, the transmitter was driven at 10Mps and/or with 100' (31m) CAT 5 cable, the transmitters were loaded with an RS-485 receiver in parallel with 54Ω.
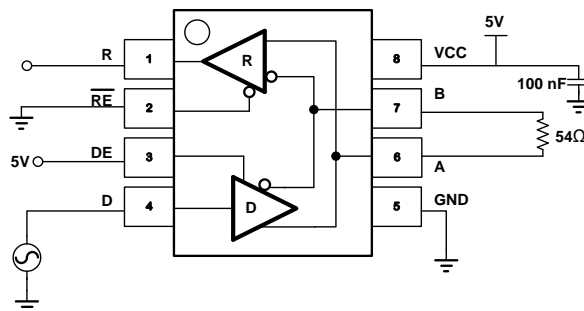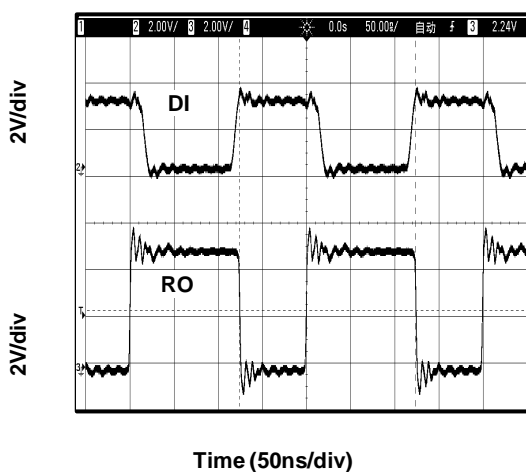


**Figure 7. Loopback Test Circuit**



Time (50ns/div)

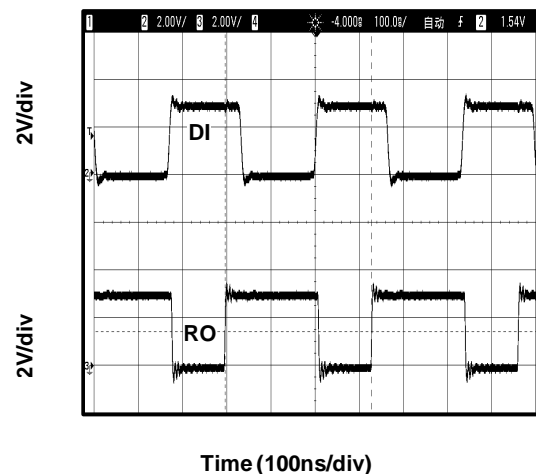**Figure 8.   Loopback Test at 10Mbps/5V**
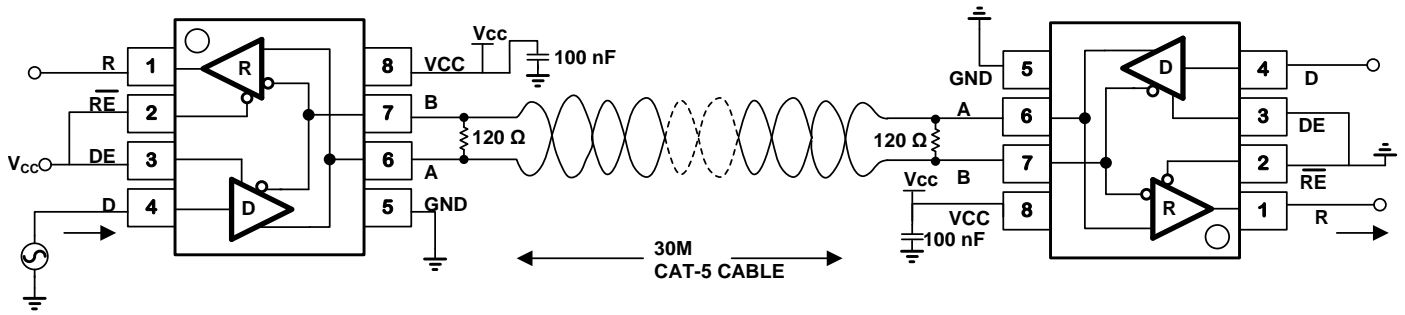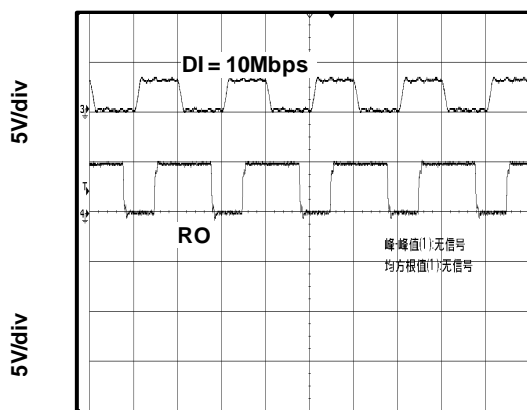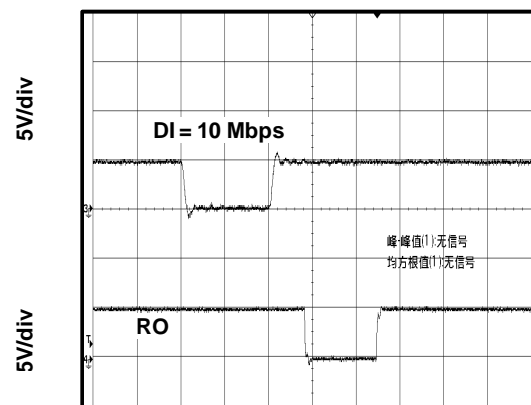


Time (100ns/div)

**Figure 9.   Loopback Test at 6Mbps/3V**
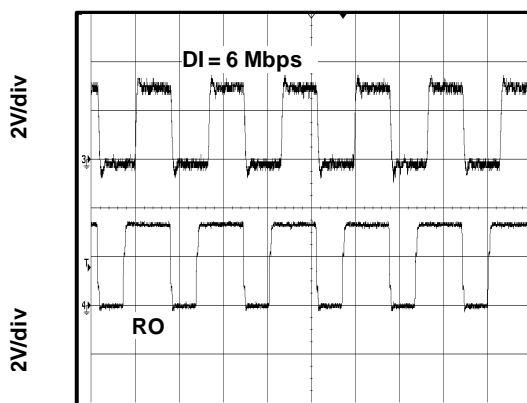
**Figure 10. 10Mbps Data Rate With 30M CAT5 Cable Test Circuit**



**Figure 11.   5V Driver and Receiver Five Pulse Waveforms Driving 100 Feet (30 Meters)**



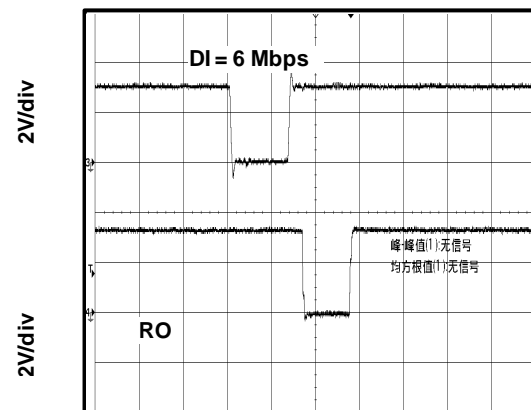**Figure 12.   5V Driver and Receiver Single Pulse Waveforms Driving 100 Feet (30 Meters)**



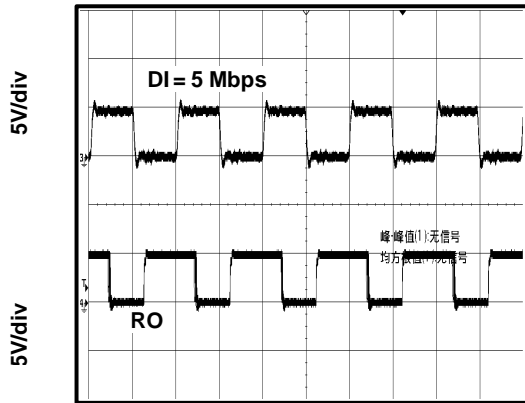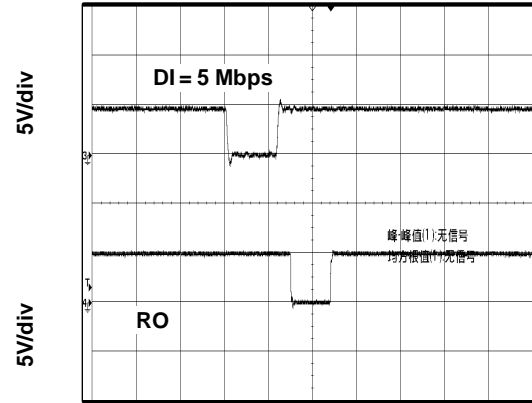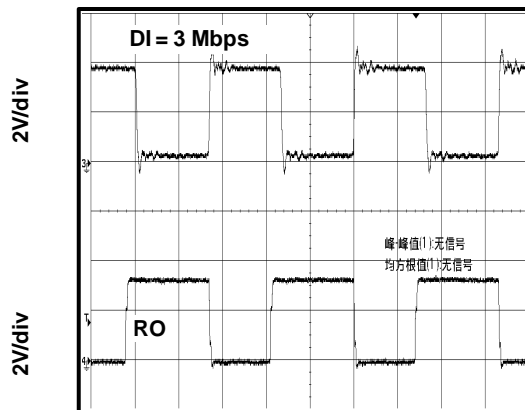**Figure 13.   3.3V Driver and Receiver Five Pulse Pulse Waveforms Driving 100 Feet (30 Meters)**



**Figure 14.   3.3V Driver and Receiver Single Waveforms Driving 100 Feet (30 Meters)**

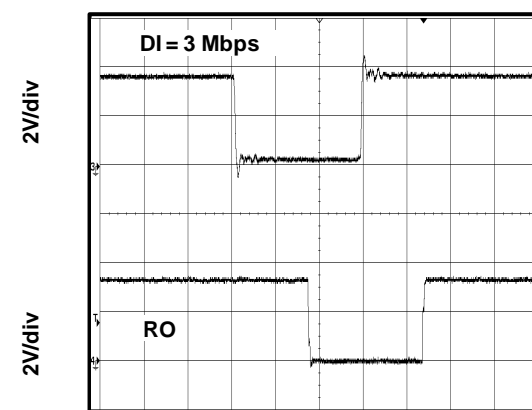**Figure 15. 5V Driver and Receiver Five Pulse Waveforms Driving 100 Feet (30 Meters)**



**Figure 16. 5V Driver and Receiver Single Pulse Waveforms Driving 100 Feet (30 Meters)**



**Figure 17. 3.3V Driver and Receiver Four Pulse Pulse Waveforms Driving 100 Feet (30 Meters)**



**Figure 18. 5V Driver and Receiver Single Waveforms Driving 100 Feet (30 Meters)**

**Full Fail-Safe**

All the receivers include a "full fail-safe" function that guarantees a high level receiver output if the receiver inputs are unconnected (floating), shorted together, or connected to a terminated bus with all the transmitters disabled. Receivers easily meet the data rates supported by the corresponding driver, and all receiver outputs are three-stable via the active low RE input.

**Hot Plug Function**

When a piece of equipment powers up, there is a period of time where the processor or ASIC driving the RS-485 control lines (DE, RE) is unable to ensure that the RS-485 Tx and Rx outputs are kept disabled. If the equipment is connected to the bus, a driver activating prematurely during power-up may crash the bus. To avoid this scenario, the TPT75176H devices incorporate a "Hot Plug" function. Circuitry monitoring VCC ensures that, during power-up and power-down, the Tx and Rx outputs remain disabled, regardless

of the state of DE and RE, if VCC is less than ~2.5V. This gives the processor/ASIC a chance to stabilize and drive the RS-485 control lines to the proper states.
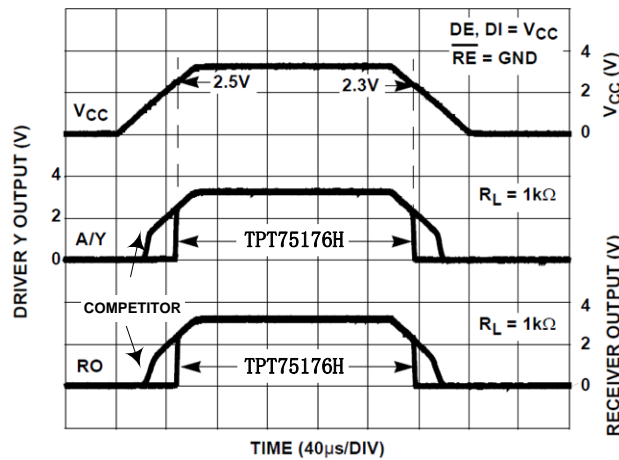


**FIGURE 19. Hot Plug Performance (TPT75176H) vs Competitor Without Hot Plug Circuitry**

## Transient Protection

The bus terminals of the TPT75176H transceiver family possess on-chip ESD protection against ±15 kV HBM. The International Electrotechnical Commision (IEC) ESD test is far more severe than the HBM ESD test. The 50% higher charge capacitance, CS, and 78% lower discharge resistance, RD of the IEC model produce significantly higher discharge currents than the HBM model.

As stated in the IEC 61000-4-2 standard, contact discharge is the preferred transient protection test method. Although IEC air-gap testing is less repeatable than contact testing, air discharge protection levels are inferred from the contact discharge test results.
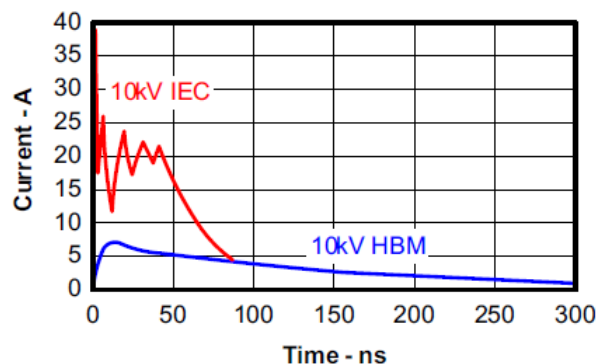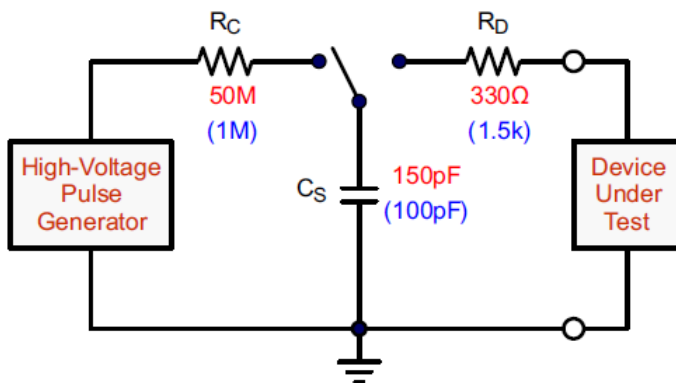


**Figure 20. HBM and IEC-ESD Models and Currents in Comparison (HBM Values in Parenthesis)**

The on-chip implementation of IEC ESD protection significantly increases the robustness of equipment. Common discharge events occur because of human contact with connectors and cables. Designers may choose to implement protection against longer duration transients, typically referred to as surge transients. Figure 9 suggests two circuit designs providing protection against short and long duration surge transients, in addition to ESD and Electrical Fast Transients (EFT) transients. Table 1 lists the bill of materials for the external protection devices.

EFTs are generally caused by relay-contact bounce or the interruption of inductive loads. Surge transients often result from lightning strikes (direct strike or an indirect strike which induce voltages and currents), or the switching of power systems, including load changes and short circuits switching. These transients are often encountered in industrial environments, such as factory automation

and power-grid systems. Figure 10 compares the pulse-power of the EFT and surge transients with the power caused by an IEC ESD transient. In the diagram on the left of Figure 10, the tiny blue blip in the bottom left corner represents the power of a 10-kV ESD transient, which already dwarfs against the significantly higher EFT power spike, and certainly dwarfs against the 500-V surge transient. This type of transient power is well representative of factory environments in industrial and process automation. The diagram on the fright of Figure 10 compares the enormous power of a 6-kV surge transient, most likely occurring in e-metering applications of power generating and power grid systems, with the aforementioned 500-V surge transient.
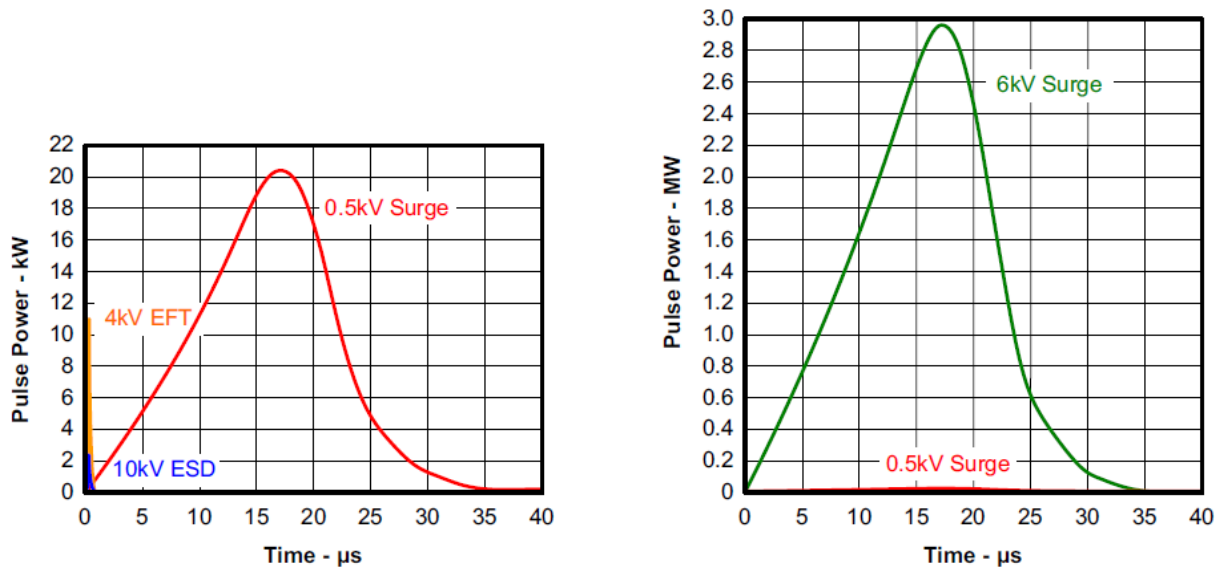


**Figure 21. Power Comparison of ESD, EFT, and Surge Transients**

In the case of surge transients, high-energy content is signified by long pulse duration and slow decaying pulse Power The electrical energy of a transient that is dumped into the internal protection cells of the transceiver is converted into thermal energy. This thermal energy heats the protection cells and literally destroys them, thus destroying the transceiver. Figure 11 shows the large differences in transient energies for single ESD, EFT, and surge transients as well as for an EFT pulse train, commonly applied during compliance testing.
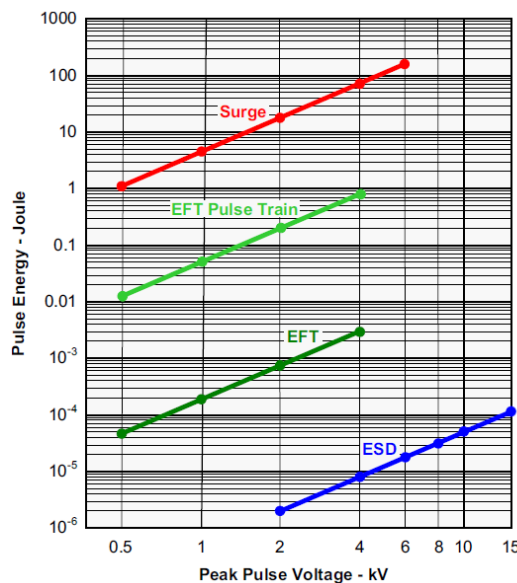


**Figure 22. Comparison of Transient Energies**

## Table 1. Bill of Materials

| Device | Function | Order Number | Manufacturer |
|---|---|---|---|
| 485 | 5-V, 10Mbps RS-485 Transceiver | TPT75176H | 3PEAK |
| R1, R2 | 10-Ω, Pulse-Proof Thick-Film Resistor | CRCW0603010RJNEAHP | Vishay |
| TVS | Bidirectional 400-W Transient Suppressor | CDSOT23-SM712 | Bourns |
| TBU1, TBU2 | Bidirectional | TBU-CA-065-200-WH | Bourns |
| MOV1, MOV2 | 200mA Transient Blocking Unit 200-V, Metal-Oxide Varistor | MOV-10D201K | Bourns |
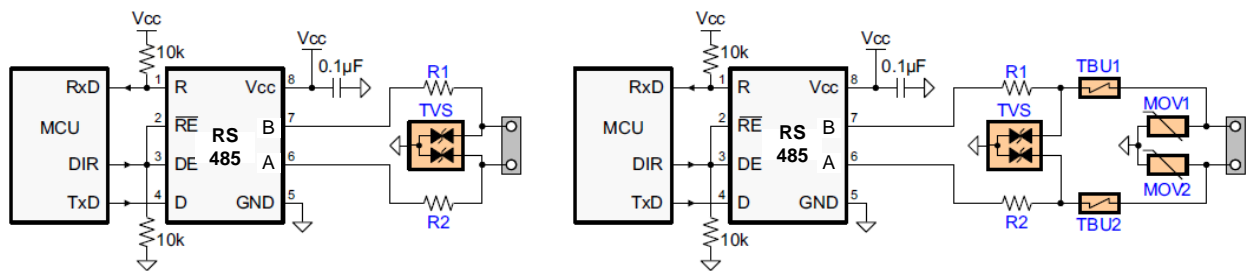


**Figure 23.   Transient Protections against ESD, EFT, and Surge Transients**

The left circuit shown in Figure 12 provides surge protection of ≥ 500-V transients, while the right protection circuits can withstand surge transients of 5 kV
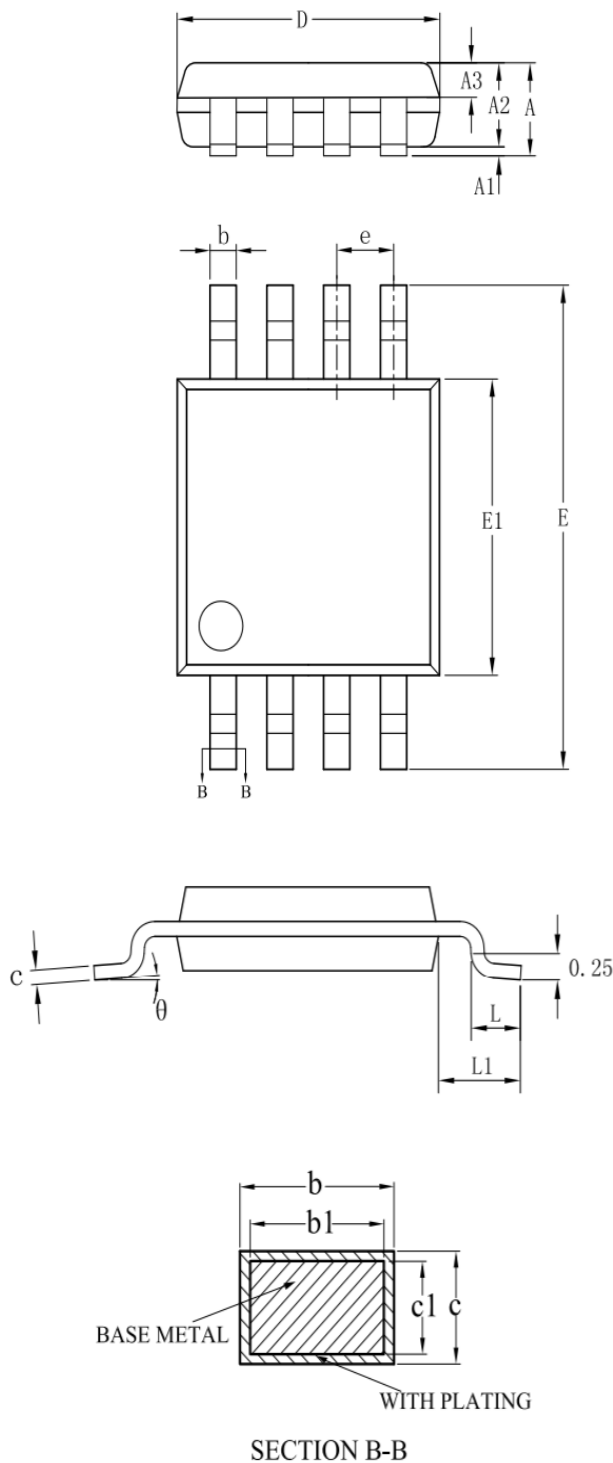
# Package Outline Dimensions

SO1R (SOP8)
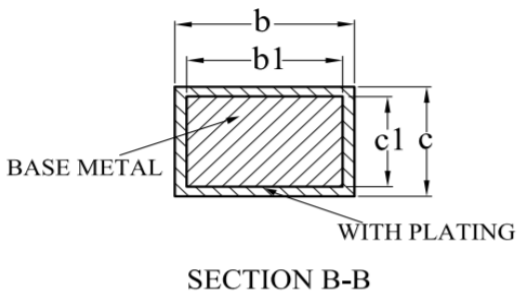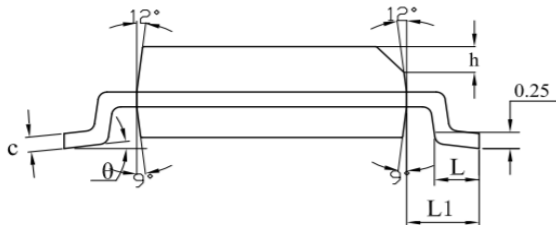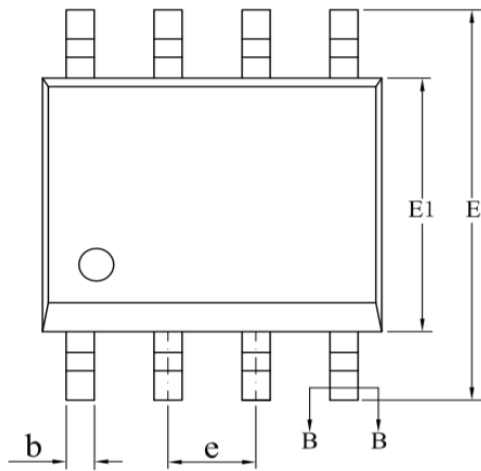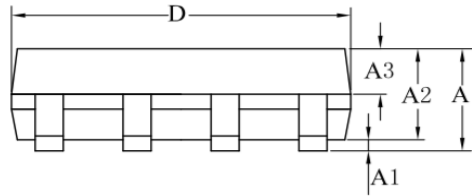


| SYMBOL | MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | — | — | 1.75 |
| A1 | 0.10 | — | 0.225 |
| A2 | 1.30 | 1.40 | 1.50 |
| A3 | 0.60 | 0.65 | 0.70 |
| b | 0.39 | — | 0.47 |
| b1 | 0.38 | 0.41 | 0.44 |
| c | 0.20 | — | 0.24 |
| c1 | 0.19 | 0.20 | 0.21 |
| D | 4.80 | 4.90 | 5.00 |
| E | 5.80 | 6.00 | 6.20 |
| E1 | 3.80 | 3.90 | 4.00 |
| e | 1.27BSC | | |
| h | 0.25 | — | 0.50 |
| L | 0.50 | — | 0.80 |
| L1 | 1.05REF | | |
| θ | 0 | — | 8° |

# Package Outline Dimensions

VS1R (MSOP8)

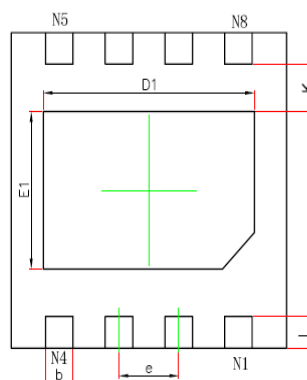| SYMBOL | MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | — | — | 1.10 |
| A1 | 0.05 | — | 0.15 |
| A2 | 0.75 | 0.85 | 0.95 |
| A3 | 0.30 | 0.35 | 0.40 |
| b | 0.28 | — | 0.36 |
| b1 | 0.27 | 0.30 | 0.33 |
| c | 0.15 | — | 0.19 |
| c1 | 0.14 | 0.15 | 0.16 |
| D | 2.90 | 3.00 | 3.10 |
| E | 4.70 | 4.90 | 5.10 |
| E1 | 2.90 | 3.00 | 3.10 |
| e | 0.65BSC | | |
| L | 0.40 | — | 0.70 |
| L1 | 0.95REF | | |
| θ | 0 | — | 8° |

SECTION B-B

## Package Outline Dimensions
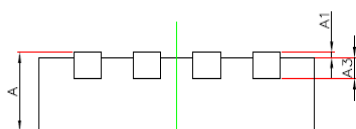
DF6R (DFN3X3-8L)

DFNWB3×3-8L-F(P0.65T0.75/0.85) PACKAGE OUTLINE DIMENSIONS
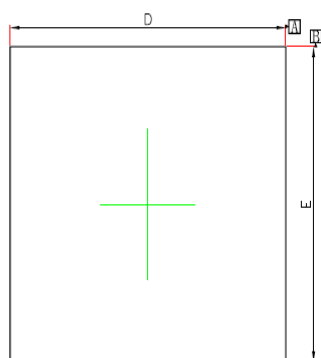
TOP VIEW

BOTTOM VIEW

SIDE VIEW

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min. | NOM. | Min. | NOM. |
| A | 0.700/0.800 | 0.800/0.900 | 0.028/0.031 | 0.031/0.035 |
| A1 | 0.000 | 0.050 | 0.000 | 0.002 |
| A3 | 0.203REF. | | 0.008REF. | |
| D | 3.000BSC. | | 0.118BSC. | |
| E | 3.000BSC. | | 0.118BSC. | |
| D1 | 2.200 | 2.400 | 0.087 | 0.094 |
| E1 | 1.400 | 1.600 | 0.055 | 0.063 |
| k | 0.250MIN. | | 0.010MIN. | |
| b | 0.250 | 0.350 | 0.010 | 0.014 |
| e | 0.650TYP. | | 0.026TYP. | |
| L | 0.224 | 0.376 | 0.009 | 0.015 |