## Features

- **Exceeds Requirements of EIA-485 Standard**
- **Bus-Polarity Correction within 100 ms ($t_{FS}$)**
- **Data Rate: 300 bps to 250 kbps**
- **Works with Two Configurations:**
  - **– Failsafe Resistors Only**
  - **– Failsafe and Differential Termination Resistors**
- **Up to 256 Nodes on a Bus (1/8 unit load)**
- **Wide Supply Voltage 3V to 5.5V**
- **SOIC-8 Package for Backward Compatibility**
- **Bus-Pin Protection:**
  - **– ±18 kV HBM protection**
  - **– ±13 kV IEC61000-4-2 Contact Discharge**
  - **– +4 kV IEC61000-4-4 Fast Transient Burst**

## Applications

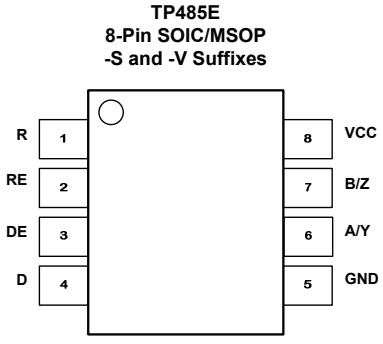
- E-Metering Networks
- Industrial Automation
- HVAC Systems
- Process Control
- DMX512-Networks
- Battery-Powered Applications

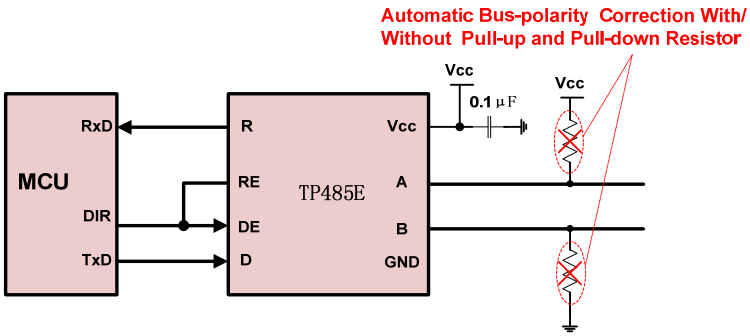
## Description

The TP485E is a low-power RS-485 transceiver with automatic bus-polarity correction and transient protection. Upon hot plug-in, the device detects and corrects the bus polarity within the first 100 ms of bus idling. On-chip transient protection protects the device against IEC61000 ESD and EFT transients. This device has robust drivers and receivers for demanding industrial applications. The bus pins are robust to electrostatic discharge (ESD) events, with high levels of protection to Human-Body Model (HBM), Air-Gap Discharge, and Contact Discharge specifications. The device combines a differential driver and a differential receiver, which operate together from a single 5-V power supply. The driver differential outputs and the receiver differential inputs are connected internally to form a bus port suitable for half-duplex(two-wire bus) communication. The device features a wide common-mode voltage range making the device suitable for multi-point applications over long cable runs. The TP485E is available in both SOIC-8 and MSOP-8 package, and is characterized from –40°C to 125°C.

3PEAK and the 3PEAK logo are registered trademarks of 3PEAK INCORPORATED. All other trademarks are the property of their respective owners.

## Pin Configuration (Top View)



## Order Information

| Model Name | Order Number | Package | Transport Media, Quantity | Marking Information |
|---|---|---|---|---|
| TP485E | TP485E-SR | 8-Pin SOIC | Tape and Reel, 4,000 | TP485E |
| TP485E | TP485E-VR | 8-Pin MSOP | Tape and Reel, 3,000 | TP485E |

### 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 |
| **POLARITY-CORRECTING MODE(1)** | | | | |
| H | H | L | H | Actively drives bus Low |
| L | H | H | L | Actively drives bus High |
| X | L | Z | Z | Driver disabled |
| X | OPEN | Z | Z | Driver disabled by default |
| OPEN | H | L | H | Actively drives bus Low |

(1) The polarity-correcting mode is entered when $V_{ID} < V_{IT-}$ and $t > t_{FS}$ and DE = low. This state is latched when /RE turns from Low to 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 | ? | Indeterminate bus state |
| **POLARITY-CORRECTING MODE(1)** | | | |
| $V_{IT+} < V_{ID}$ | L | L | Receive valid bus Low |
| $V_{IT-} < V_{ID} < V_{IT+}$ | L | ? | Indeterminate bus state |
| $V_{ID} < V_{IT-}$ | L | H | Receive polarity corrected bus High |
| X | H | Z | Receiver disabled |
| X | OPEN | Z | Receiver disabled |
| Open, short, idle Bus | L | ? | Indeterminate bus state |

(1) The polarity-correcting mode is entered when $V_{ID} < V_{IT-}$ and $t > t_{FS}$ and DE = low. This state is latched when /RE turns from Low to High.

## Absolute Maximum Ratings

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

Input Voltages

DI, DE, RE.....-0.3V to (VCC + 0.3V)

Input/Output Voltages

A/Y, B/Z, A, B, Y, Z.....-15V to +15V

A/Y, B/Z, A, B, Y, Z (Transient Pulse Through 100Ω,

Note 1)..... ±100V

RO..... -0.3V to (VCC +0.3V)

Short Circuit Duration

Y, Z.....Continuous

ESD Rating.....See Specification Table

## Recommended Operating Conditions Note 2

Supply Voltage.....3V to 5.5V

Temperature Range.....-40°C to +125°C

Bus Pin Common Mode Voltage Range .....-8V to +13V

Thermal Resistance, ΘJA (Typical)

8-Pin SOIC Package .....158°C/W

8-Pin MSOP Package .....210°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).

Note 2: Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

## Electrical Characteristics

Test Conditions: VCC = 5V, Over operating free-air temperature range(unless otherwise noted)

| PARAMETER | | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| $\|V_{OD}\|$ | Driver differential-output voltage magnitude | RL = 60 Ω | See Figure 1B | | 2.6 | | V |
| | | RL = 54 Ω with $V_A$ or $V_B$ from –7 to +12 V, $V_{CC}$ = 5V (RS-485) | See Figure 1A | 2.4 | 2.6 | | |
| | | RL = 54 Ω with VA or VB from -7 to +12 V, VCC = 3V (RS-485) | | 1.4 | 1.5 | | |
| | | RL = 100 Ω(RS-422) | | | 3 | | |
| $\Delta\|V_{OD}\|$ | Change in magnitude of driver differential-output voltage | RL = 54 Ω, CL=50pF | See Figure 1A | -0.01 | 0 | 0.03 | V |
| $V_{OC(SS)}$ | Steady-stage common-mode output voltage | Center of two 27-Ω load resistors | See Figure 1A | Vcc/2-0.2 | $V_{CC}$/2 | Vcc/2+0.2 | V |
| $\Delta V_{OC}$ | Change in differential driver common-mode output voltage | | | -0.2 | 0 | 0.2 | 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 | | | | 75 | | mV |
| $V_{IT-}$ | Negative-going receiver differential-input voltage threshold | | | | -75 | | mV |
| $V_{HYS}$ (1) | Receiver differential-input voltage threshold hysteresis ($V_{IT+} – V_{IT–}$) | | | | 150 | | mV |
| $V_{OH}$ | Receiver high-level output voltage | $I_{OH}$= -8 mA | | 4.64 | 4.65 | 4.66 | V |
| $V_{OL}$ | Receiver low-level output voltage | $I_{OL}$= 8 mA | | 0.22 | 0.23 | 0.24 | V |
| $I_I$ | Driver input, driver enable and receiver enable input current | | | 0.012 | 0.017 | 0.022 | μA |
| $I_{OZ}$ | Receiver high-impedance output current | VO = 0 V or VCC, /RE at VCC | | -0.003 | 0 | 0.01 | μA |
| $\|I_{OS}\|$ | Driver short-circuit output current | $\|I_{OS}\|$ with $V_A$ or $V_B$ from –7 to +12 V | | | 80 | 107 | mA |
| $I_I$ | 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 | | 55 | 65 | μA |
| | | | VI= -7 V | -63 | -50 | | |
| $I_{CC}$ | Supply current(quiescent) | Driver and receiver enabled | DE = $V_{CC}$, /RE = GND, No LOAD | 624 | 680 | 771 | μA |
| | | Driver enabled, receiver disabled | DE = $V_{CC}$, /RE = $V_{CC}$, No LOAD | 269 | 278 | 290 | |
| | | Driver disabled, receiver enabled | DE = GND, /RE = $V_{CC}$, No LOAD | 458 | 500 | 546 | |
| | | Driver and receiver disabled | DE = GND, /RE = $V_{CC}$, D= $V_{cc}$ No LOAD | 0.017 | 0.15 | 0.177 | |
| | Supply current(dynamic) | See | | | | | |

## Switching CHARACTERISTICS

.3.3ms > bit time> 4μs(unless otherwise noted)

| PARAMETER | | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DRIVER** | | | | | | | |
| $t_r$, $t_f$ | Driver differential-output rise and fall times | RL = 54 Ω, CL=50pF | See Figure 2 | | 620 | | ns |
| $t_{PHL}$, $t_{PLH}$ | Driver propagation delay | | | | 340 | | |
| $t_{SK(P)}$ | Driver pulse skew, $\|t_{PHL} - t_{PLH}\|$ | | | | 23 | | |
| $t_{PHZ}$, $t_{PLZ}$ | Driver disable time | | See Figure 3 | | 250 | | ns |
| $t_{PHZ}$, $t_{PLZ}$ | Driver enable time | Receiver enabled | | | 562 | | ns |
| | | Receiver disabled | | | 562 | | |
| **RECEIVER** | | | | | | | |
| tr, tf | Receiver output rise and fall times | CL=15 pF | See Figure 5 | | 12.4 | | ns |
| $t_{PHL}$, $t_{PLH}$ | Receiver propagation delay time | | | | 960 | | |
| $t_{SK(P)}$ | Receiver pulse skew, $\|t_{PHL} - t_{PLH}\|$ | | | | 40 | | |
| $t_{PHZ}$, $t_{PLZ}$ | Receiver disable time | | | | 7 | | ns |
| $t_{PZL(1)}$, $t_{PZH(1)}$ $t_{PZL(2)}$, $t_{PZH(2)}$ | Receiver enable time | Driver enabled | See Figure 6 | | 70 | | ns |
| | | Driver disabled | See Figure 6 | | 989 | | |
| $t_{FS}$ | Bus failsafe time | Driver disabled | See Figure 6 | 88 | 100 | 107 | ms |

## Test Circuits and Waveforms

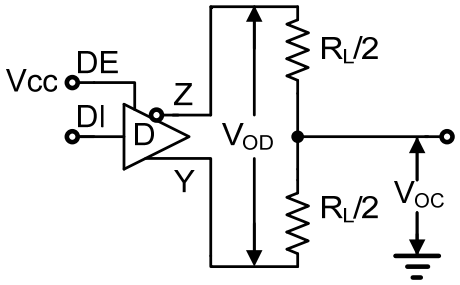



FIGURE 1A. VOD AND VOC

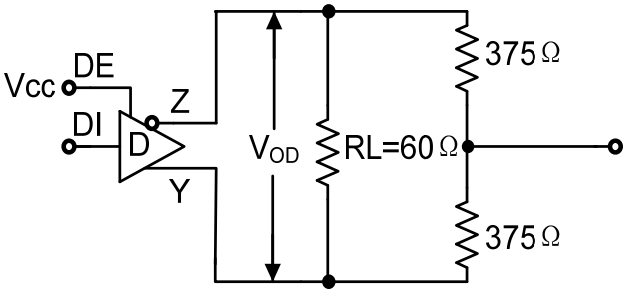



FIGURE 1B. VOD WITH COMMON MODE LOAD

FIGURE 1. DC DRIVER TEST CIRCUITS

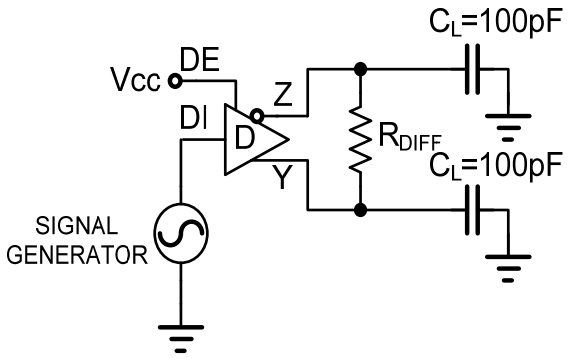



FIGURE 2A. TEST CIRCUIT

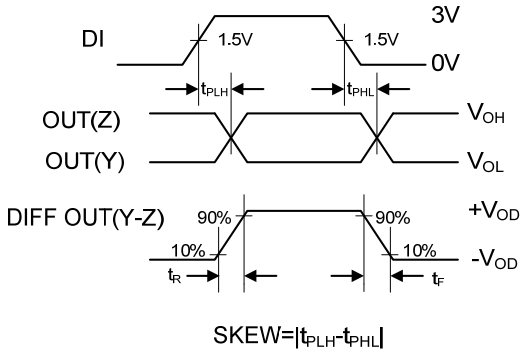
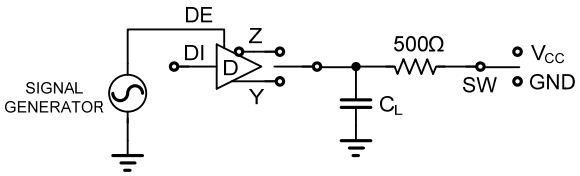



FIGURE 2B. MEASUREMENT POINTS

FIGURE 2. DRIVER PROPAGATION DELAY AND DIFFERENTIAL TRANSITION TIMES




| PARAMETER | OUTPUT | RE | DI | SW | CL (pF) |
|---|---|---|---|---|---|
| tHZ | Y/Z | X | 1/0 | GND | 15 |
| tLZ | Y/Z | X | 0/1 | VCC | 15 |
| tZH | Y/Z | 0 (Note 9) | 1/0 | GND | 100 |
| tZL | Y/Z | 0 (Note 9) | 0/1 | VCC | 100 |
| tZH(SHDN) | Y/Z | 1 (Note 12) | 1/0 | GND | 100 |
| tZL(SHDN) | Y/Z | 1 (Note 12) | 0/1 | VCC | 100 |

FIGURE 3A. TEST CIRCUIT

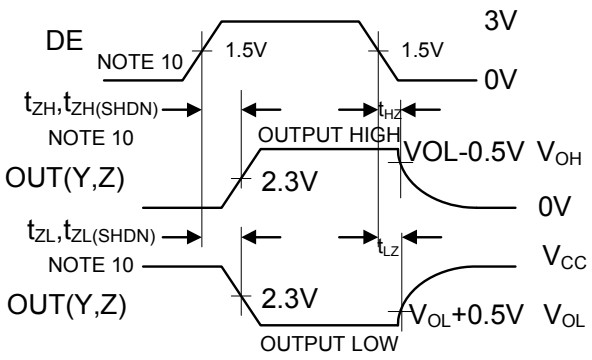



FIGURE 3B. MEASUREMENT POINTS

FIGURE 3. DRIVER ENABLE AND DISABLE TIMES

## Test Circuits and Waveforms(continue)

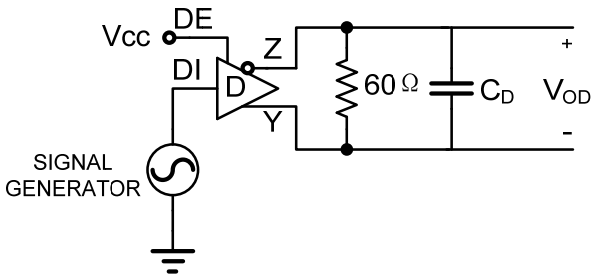



FIGURE 4A. TEST CIRCUIT

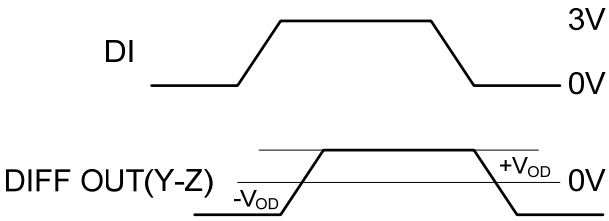



FIGURE 4B. MEASUREMENT POINTS

FIGURE 4. DRIVER DATA RATE

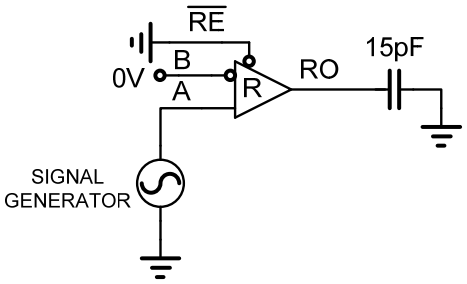



FIGURE 5A. TEST CIRCUIT

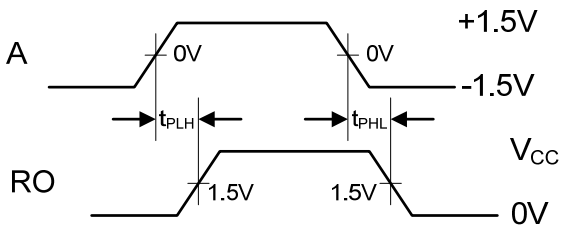
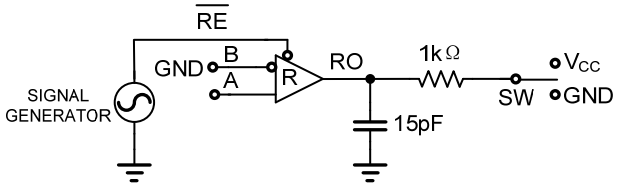



FIGURE 5B. MEASUREMENT POINTS

FIGURE 5. RECEIVER PROPAGATION DELAY AND DATA RATE




| PARAMETER | DE | A | SW |
|---|---|---|---|
| tHZ | 0 | +1.5V | GND |
| tLZ | 0 | -1.5V | VCC |
| tZH(Note 10) | 0 | +1.5V | GND |
| tZL(Note 10) | 0 | -1.5V | VCC |
| tZH(SHDN)(Note 13) | 0 | +1.5V | GND |
| tZL(SHDN)(Note 13) | 0 | -1.5V | VCC |

FIGURE 6A. TEST CIRCUIT

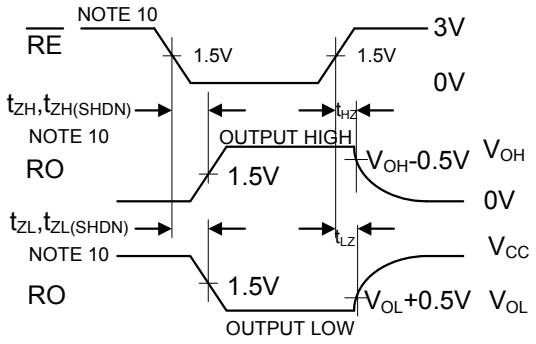



FIGURE 6B. MEASUREMENT POINTS

FIGURE 6. RECEIVER ENABLE AND DISABLE TIMES

## Detailed Description

The TP485E half-duplex RS-485 transceiver features automatic polarity correction on the RS-485 bus lines. This device also includes fail-safe circuitry, which guarantees a logic-high receiver output when the receiver inputs are open or shorted, or when connected to a terminated transmission line with all drivers disabled. Hot-swap capability on the enable inputs allows line insertion without erroneous data transfer and controlled slew-rate drivers minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free data transmission up to 250 kbps. The TP485E features short-circuit current limits on the driver and receiver outputs and thermal shutdown circuitry to protect against excessive power dissipation.

### Automatic Polarity Detection

The TP485E is designed to detect and correct installation-based connections on RS-485 lines. With the driver disabled, internal detection circuitry samples the voltages at the A and B inputs during an idle period (100ms, typ) and configures the driver and receiver for the detected polarity. Polarity is swapped only when $|V_A - V_B| > 75mV$ for the idle period. The A/B line polarity can be defined by a pull up and pull down resistor pair on the A/B lines, for example, in the RS-485 Half duplex master terminal (see the *Typical Operating Circuit*). When the polarity is normal, A is the non inverting receiver input/driver output and B is the inverting input/output. When the polarity is inverted, A is the inverting input/output and B is the non inverting input/output.

To allow the bus to define A/B polarity, connect one pull up/pull down resistor pair to the bus to set the bus status during the idle periods. It is preferable to locate the resistor pair in the bus master, as shown in Figure 7.

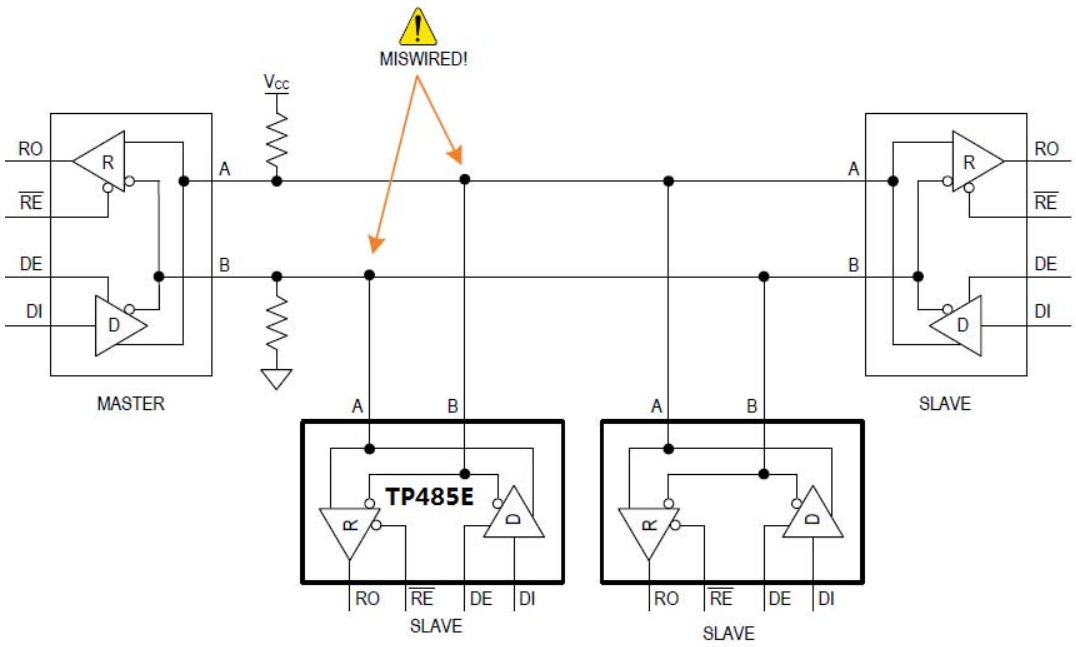



**Figure 7. Polarity Definition**

### 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 TP485E devices incorporate a “Hot Plug” function. Circuitry monitoring $V_{CC}$ ensures that, during power-up and power-down, the Tx and Rx outputs remain disabled, regardless of the state of DE and RE, if $V_{CC}$ 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.

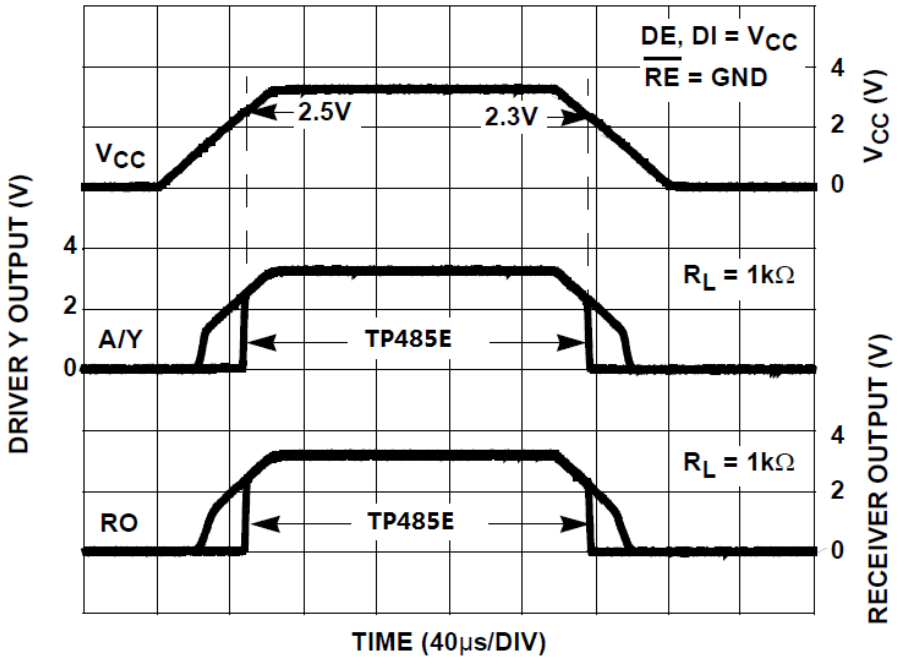



**FIGURE 8. HOT PLUG PERFORMANCE (TP485E) vs Competitor WITHOUT HOT PLUG CIRCUITRY**

### ESD Protection

All pins on these devices include class 3 (>7 kV) Human Body Model (HBM) ESD protection structures, but the RS-485 pins (driver outputs and receiver inputs) incorporate advanced structures allowing them to survive ESD events in excess of ±18 kV HBM and ±13 kV (1/2 duplex) IEC61000-4-2. The RS-485 pins are particularly vulnerable to ESD strikes because they typically connect to an exposed port on the exterior of the finished product. Simply touching the port pins, or connecting a cable, can cause an ESD event that might destroy unprotected ICs. These new ESD structures protect the device whether or not it is powered up, and without degrading the RS-485 common mode range of -7V to +12V. This built-in ESD protection eliminates the need for board level protection structures (e.g., transient suppression diodes), and the associated, undesirable capacitive load they present.

### Transient Protection

The bus terminals of the TP485E transceiver family possess on-chip ESD protection against ±18 kV HBM and ±13 kV IEC61000-4-2 contact discharge. 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.

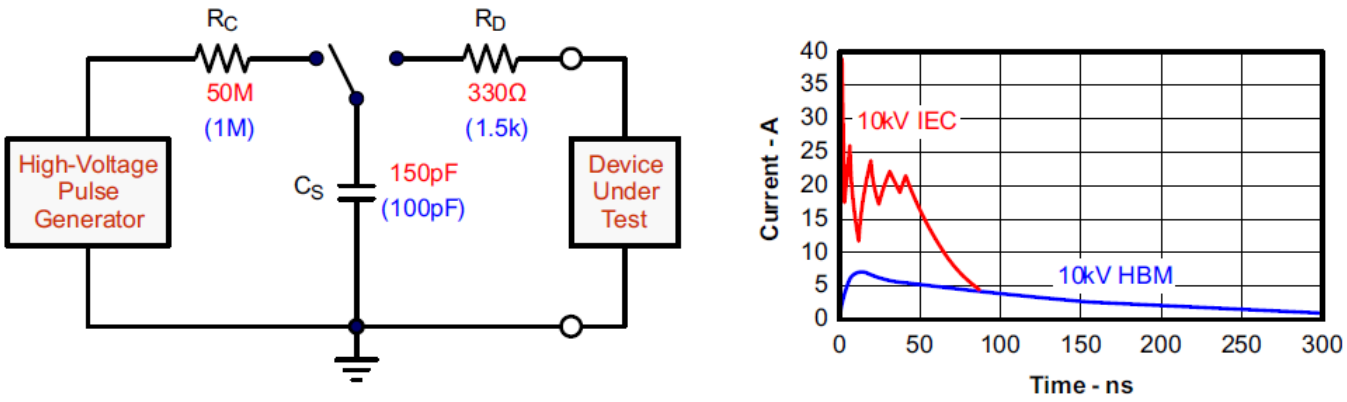



**Figure 9. HBM and IEC-ESD Models and Currents in Comparison (HBM Values in Parenthesis)**

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.

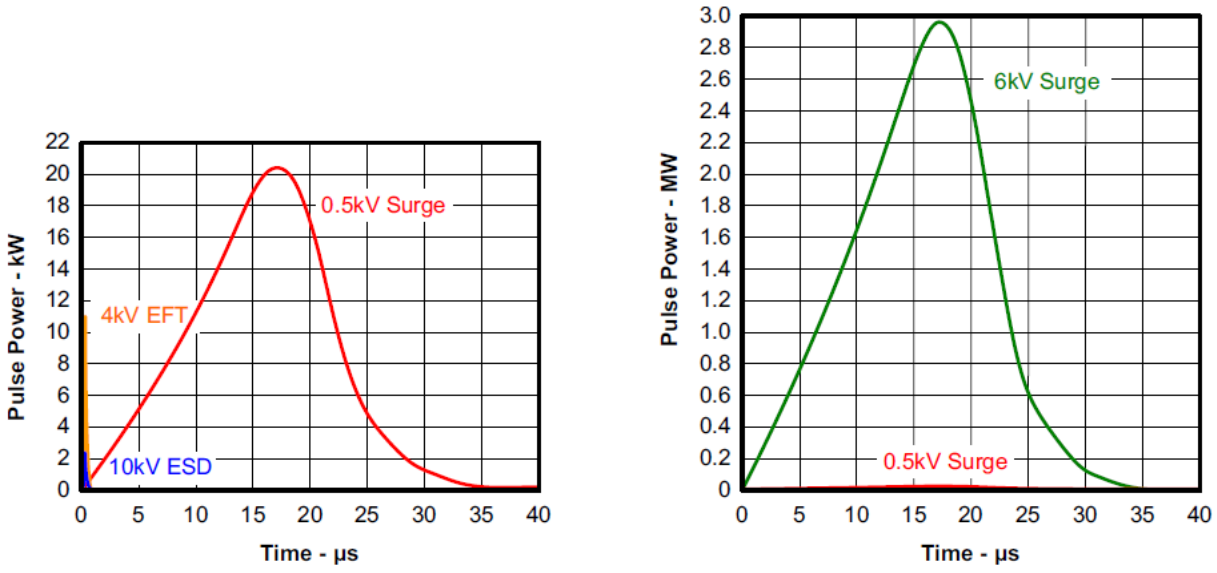



**Figure 10. Power Comparison of ESD, EFT, and Surge Transients**

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.

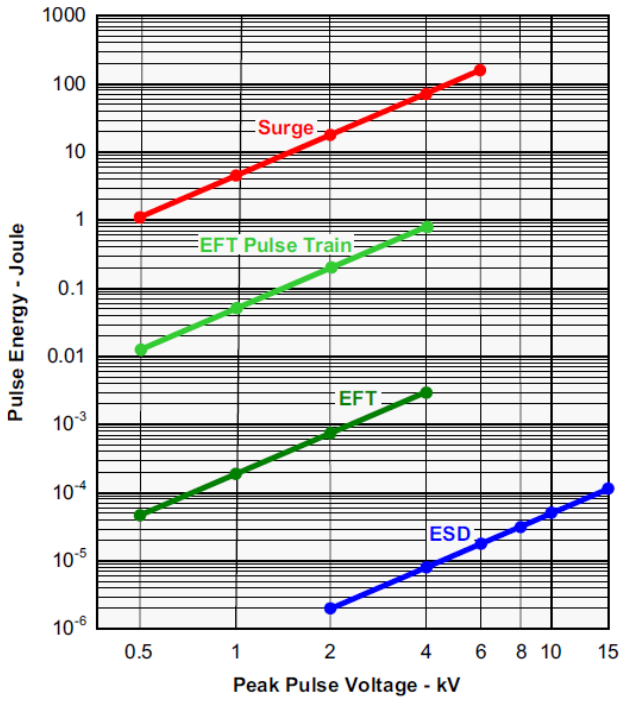



**Figure 11. Comparison of Transient Energies**

**Table 1. Bill of Materials**

| Device | Function | Order Number | Manufacturer |
|---|---|---|---|
| 485 | 5-V, 250-kbps RS-485 Transceiver | TP485E | 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 |

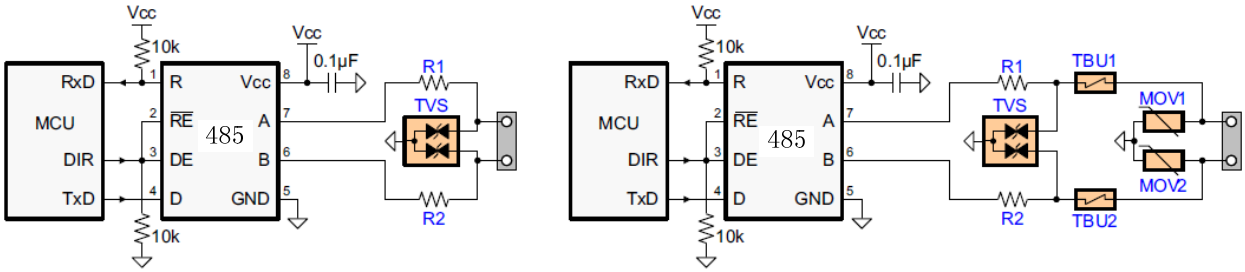



**Figure 12. Transient Protections Against ESD, EFT, and Surge Transients**

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.

## Typical Performance Characteristics

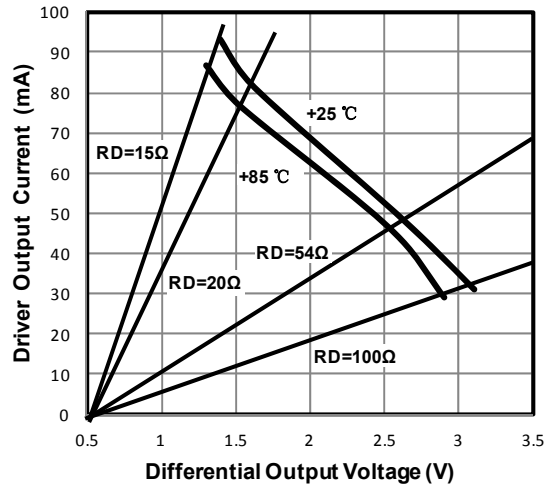



FIGURE 13. DRIVER OUTPUT CURRENT vs VOLTAGE DIFFERENTIAL OUTPUT VOLTAGE

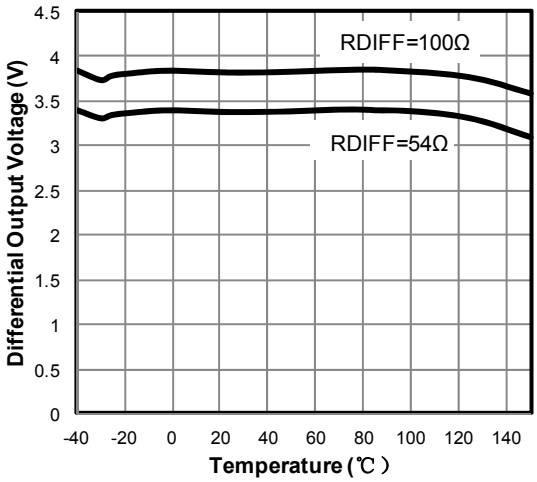



FIGURE 14. DRIVER DIFFERENTIAL OUTPUT vs TEMPERATURE

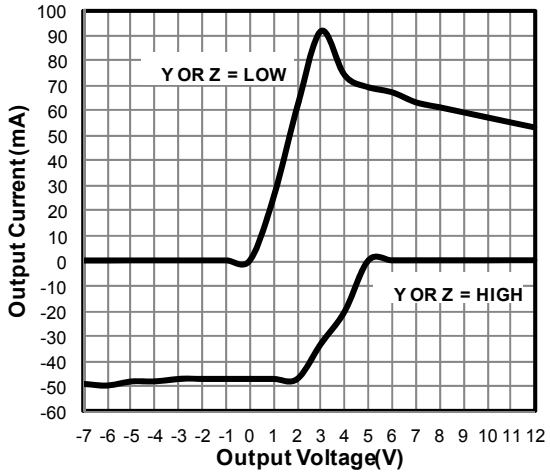



FIGURE 15. DRIVER OUTPUT CURRENT vs SHORT CIRCUIT VOLTAGE

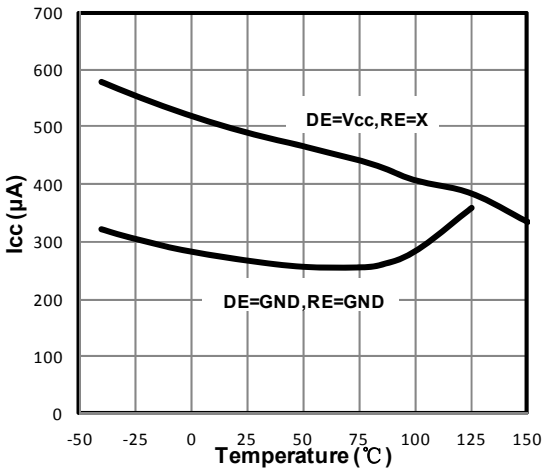



FIGURE 16. SUPPLY CURRENT vs TEMPERATURE

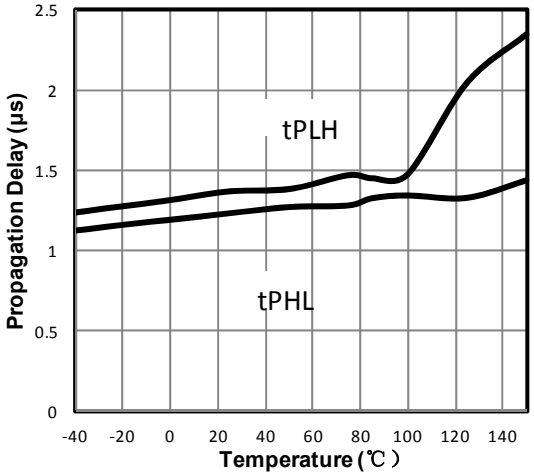



FIGURE 17. DRIVER DIFFERENTIAL PROPAGATION DELAY vs TEMPERATURE

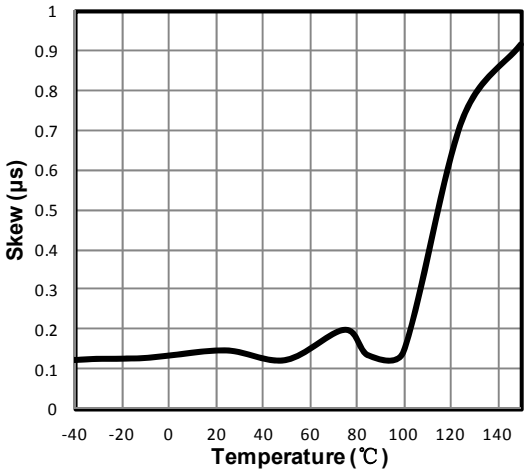



FIGURE 18. DRIVER DIFFERENTIAL SKEW vs TEMPERATURE

## Typical Performance Curves

$V_{CC}$ = 5V, $T_A$ = +25°C; Unless Otherwise Specified.

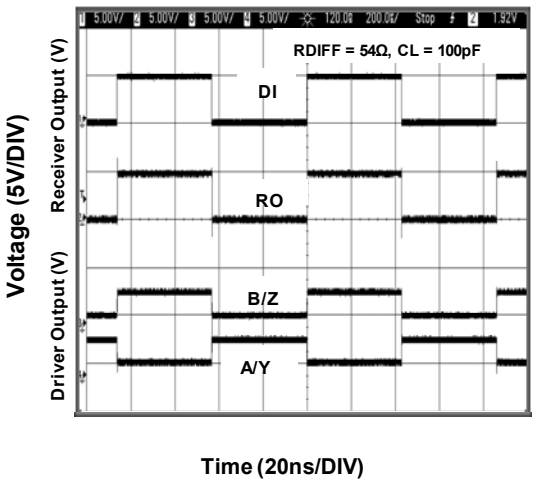
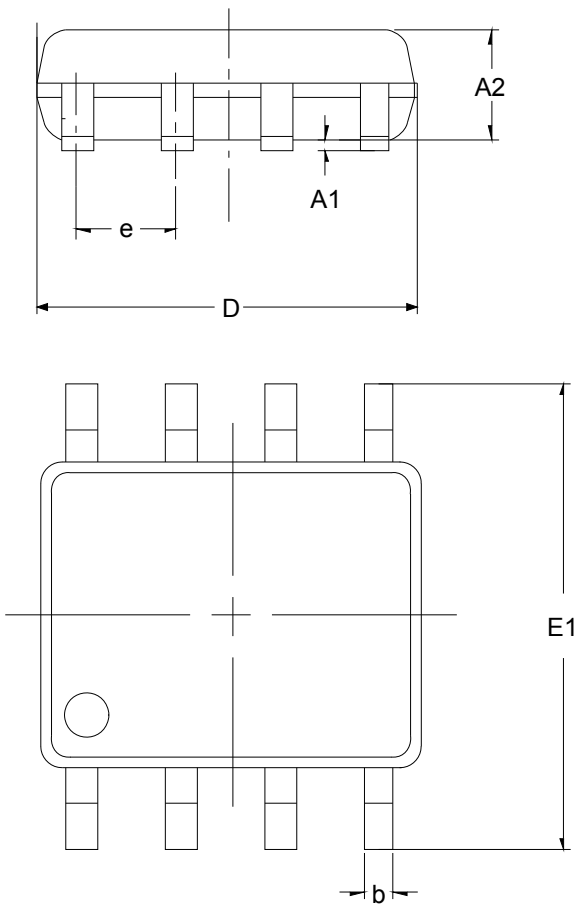



**FIGURE 19. DRIVER AND RECEIVER WAVEFORMS**

## Package Outline Dimensions

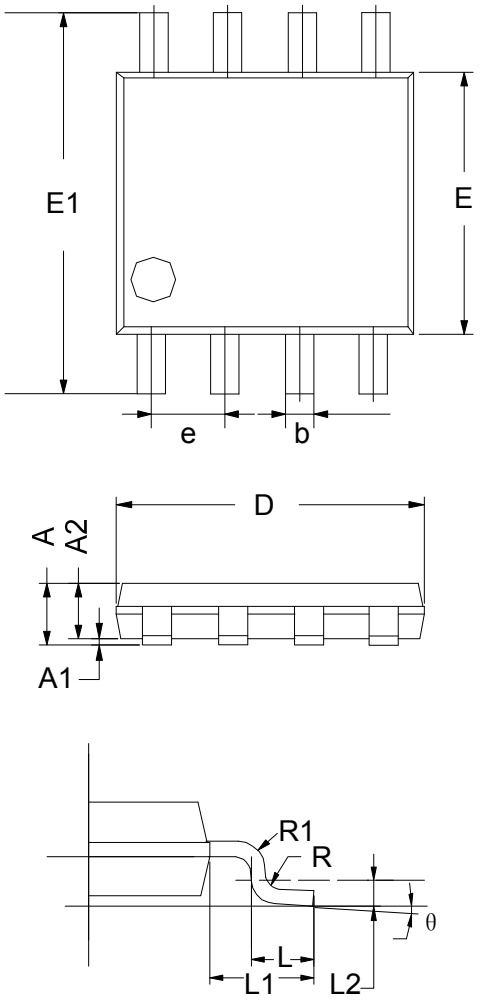
SO-8 (SOIC-8)




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A1 | 0.100 | 0.250 | 0.004 | 0.010 |
| A2 | 1.350 | 1.550 | 0.053 | 0.061 |
| b | 0.330 | 0.510 | 0.013 | 0.020 |
| C | 0.190 | 0.250 | 0.007 | 0.010 |
| D | 4.780 | 5.000 | 0.188 | 0.197 |
| E | 3.800 | 4.000 | 0.150 | 0.157 |
| E1 | 5.800 | 6.300 | 0.228 | 0.248 |
| e | 1.270 TYP | | 0.050 TYP | |
| L1 | 0.400 | 1.270 | 0.016 | 0.050 |
| θ | 0° | 8° | 0° | 8° |

## Package Outline Dimensions

MSOP-8




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.800 | 1.200 | 0.031 | 0.047 |
| A1 | 0.000 | 0.200 | 0.000 | 0.008 |
| A2 | 0.760 | 0.970 | 0.030 | 0.038 |
| b | 0.30 TYP | | 0.012 TYP | |
| C | 0.15 TYP | | 0.006 TYP | |
| D | 2.900 | 3.100 | 0.114 | 0.122 |
| e | 0.65 TYP | | 0.026 | |
| E | 2.900 | 3.100 | 0.114 | 0.122 |
| E1 | 4.700 | 5.100 | 0.185 | 0.201 |
| L1 | 0.410 | 0.650 | 0.016 | 0.026 |
| θ | 0° | 6° | 0° | 6° |