±12-K ESD Protection, Full Fail-Safe RS-485 Transceiver

Features

- Exceeds Requirements of EIA-485 Standard
- Hot Plug Circuitry − Tx and Rx Outputs Remain Three-State during Power-up/Power-down
- Data Rate: Up to 250 kbps
- Full Fail-Safe (Open, Short, and Terminated) Receivers
- Up to 256 Nodes on a Bus (1/8 Unit Load)
- Wide Supply Voltage: 3 V to 5.5 V
- SOP8 Package for Backward Compatibility
- Bus-Pin Protection:
  - ±12-kV HBM Protection

Applications

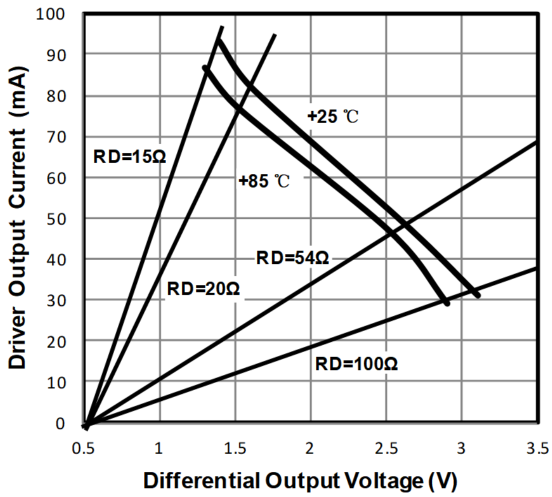
- E-Metering Networks
- Industrial Automation
- HVAC Systems
- Process Control
- DMX512-Networks
- Battery-Powered Applications

Description

The TP8485E devices are 3-V to 5.5-V powered transceivers that meet the RS-485 and RS-422 standards for balanced communication. Driver outputs and receiver inputs are protected against ±12-kV ESD strikes without latch-up.

Transmitters in this family deliver exceptional differential output voltages (2.5 V min/5 V_{CC}), into the RS-485 required 54-Ω load, for better noise immunity, or to allow up to eight 120-Ω terminations in "star" topologies. These devices have very low bus currents, so they present a true "1/8 unit load" to the RS-485 bus. This allows up to 256 transceivers on the network without using repeaters. Receiver (Rx) inputs feature a "Full Fail-Safe" design, which ensures a logic-high Rx output if Rx inputs are floating, shorted, or on a terminated but undriven bus. Rx outputs feature high drive levels, typically 25 mA @ V_{OL} = 1 V (to ease the design of optocoupled isolated interfaces).

The TP8485E devices are available in the SOP8 and MSOP8 packages, and are characterized from –40°C to 125°C.



Grade 1 Ambient Temperature Range: −40ºC to 125ºC

Table of Contents

Revision History

Date	Revision	Notes
2015-10-09	Rev.Pre.0	Initial release
2015-12-07	Rev.C	Updated the package information
2018-10-22	Rev.D	Updated the HBM ESD level
2020-07-20	Rev.E.0	Updated the typo of the pinout name
2023-05-10	Rev.E.1	Updated the typo of Recommended Operating Conditions
2024-08-22	Rev.E.2	Added Tape and Reel Information
2024-12-22	Rev.E.3	Updated to a new datasheet format Added the MSL value in the Order Information Updated the POD

Pin Configuration and Functions

TP8485E
SOP8/MSOP8
Top View

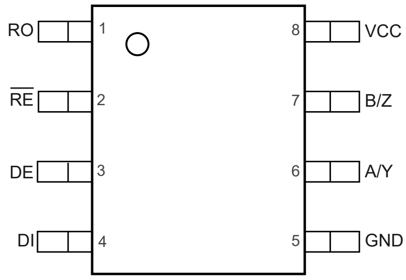


Table 1. Pin Functions: TP8485E

Pin	Name	I/O	Description
1	RO	Digital Output	Receiver output.
2	$\overline{RE}$	Digital Input	Receiver output enable.
3	DE	Digital Input	Driver output enable.
4	DI	Digital Input	Driver input.
5	GND	Ground	Ground.
6	A/Y	Bus Input/ Output	Non-inverting receiver input A and non-inverting driver output A.
7	B/Z	Bus Input/ Output	Inverting receiver input B and inverting driver output B.
8	VCC	Power	Power supply.

Functional Table

Table 2. Driver Pin Functions

Input	Enable	Outputs		Description
DI	DE	A/Y	B/Z	
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

Table 3. Receiver Pin Functions

Differential Input	Enable	Output	Description
$V_{ID} = V_A - V_B$	$\overline{RE}$	RO	
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

Specifications

Absolute Maximum Ratings (1)

Parameter	Min	Max	Unit
V_{DD} to GND	−0.3	7	V
Input Voltages DI, DE, $\overline{RE}$	−0.3	V_{CC} + 0.3	V
Input/Output Voltages A/Y, B/Z, A, B, Y, Z	−9	14	V
RO	−0.3	V_{CC} + 0.3	V
Short-Circuit Duration Y, Z		Continuous	
ESD Rating		See Specification Table	

(1) Stresses beyond the Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions.

Recommended Operating Conditions (1)

Parameter		Min	Max	Unit
	Supply Voltage	3	5.5	V
T_A	Operating Temperature Range	−40	125	°C
	Bus Pin Common-Mode Voltage Range	−7	12	V
T_J	Maximum Junction Temperature (Plastic Package)		150	°C
T_{STG}	Maximum Storage Temperature Range	−65	150	°C

(1) 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.
(2) Tested according to TIA/EIA-485-A, Section 4.2.6 (±25 V for 15 μs at a 1% duty cycle).

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOP8	120	64	°C/W
MSOP8	135	68	°C/W

Electrical Characteristics

All test conditions: V_{CC} = 5 V, over operating free-air temperature range, unless otherwise noted.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$\|V_{OD}\|$	Driver Differential-Output Voltage Magnitude	R_L = 60 Ω	Figure 10B		2.6		V
		R_L = 54 Ω with V_A or V_B from –7 V to +12 V, V_{CC} = 5 V (RS-485)		2.1	2.5		
		R_L = 54 Ω with V_A or V_B from –7 V to +12 V, V_{CC} = 3 V (RS-485)	Figure 10A	1	1.5		
		R_L = 100 Ω (RS-422)			3		
$\Delta\|V_{OD}\|$	Change in Magnitude of Driver Differential-Output Voltage	R_L = 54 Ω, C_L = 50 pF, V_{CC} = 5 V	Figure 10A	−0.2	−0.002	0.2	V
$V_{OC(SS)}$	Steady-Stage Common-Mode Output Voltage	Center of two 27-Ω load resistors	Figure 10A		V_{CC} / 2		V
ΔV_{OC}	Change in Differential Driver Common-Mode Output Voltage				0.05		V
$V_{OC(PP)}$	Peak-to-Peak Driver Common-Mode Output Voltage				0.5		
C_{OD}	Differential-Output Capacitance				8		pF
V_{IT+}	Positive-Going Receiver Differential-Input Voltage Threshold					−40	mV
V_{IT-}	Negative-Going Receiver Differential-Input Voltage Threshold			−200			mV
V_{HYS} (1)	Receiver Differential-Input Voltage Threshold Hysteresis ($V_{IT+} – V_{IT-}$)				110		mV
V_{IH}	Logic Input High Voltage	D, DE, $\overline{RE}$		2			V
V_{IL}	Logic Input Low Voltage	D, DE, $\overline{RE}$				0.4	V
V_{OH}	Receiver High-Level Output Voltage	I_{OH} = −8 mA		4	4.5		V
V_{OL}	Receiver Low-Level Output Voltage	I_{OL} = 8 mA			0.2	0.4	V

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
I_I	Driver Input, Driver Enable and Receiver Enable Input Current			−2	0.01	2	μA
I_{OZ}	Receiver High-Impedance Output Current	V_O = 0 V or V_{CC}, $\overline{RE}$ at V_{CC}		−2	0.01	2	μA
$\lvert I_{OS}\rvert$	Driver Short-Circuit Output Current	│IOS│ with V_A or V_B from –7 V to +12 V		75	80	115	mA
I_I	Bus Input Current (Driver Disabled)	V_{CC} = 4.5 V to 5.5 V or V_{CC} = 0 V, DE at 0 V	VI = 12 V		100	150	μA
			VI = −7 V	−150	−80		
I_{CC}	Supply Current (Quiescent)	Driver and receiver enabled	DE = V_{CC}, $\overline{RE}$ = GND, no load		695	900	μA
		Driver enabled, receiver disabled	DE = V_{CC}, $\overline{RE}$ = V_{CC}, no load		270	350	
		Driver disabled, receiver enabled	DE = GND, $\overline{RE}$ = V_{CC}, no load		480	600	
		Driver and receiver disabled	DE = GND, $\overline{RE}$ = V_{CC}, DI = V_{CC}, no load		1.4	5	

Switching Characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Driver							
t_r, t_f	Driver Differential-Output Rise and Fall Times	R_L = 54 Ω, C_L = 50 pF	Figure 10		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		Figure 11		250		ns
t_{PHZ}, t_{PLZ}	Driver Enable Time	Receiver enabled			562		ns
		Receiver disabled			562		
Receiver							
t_r, t_f	Receiver Output Rise and Fall Times	C_L = 15 pF	Figure 13		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}, t_{PZH}	Receiver Enable Time	Driver enabled	Figure 14		70		ns
	Receiver Enable Time	Driver disabled	Figure 14		989		
ESD							
RS-485 Pins (A, Y, B, Z, A/Y, B/Z)		Human Body Model, from bus pins to GND			±12		kV
All Other Pins		Human Body Model, per MIL-STD-883			±2		kV

Typical Performance Characteristics

All test conditions: V_{CC} = 5 V, T_A = +25°C, unless otherwise noted.

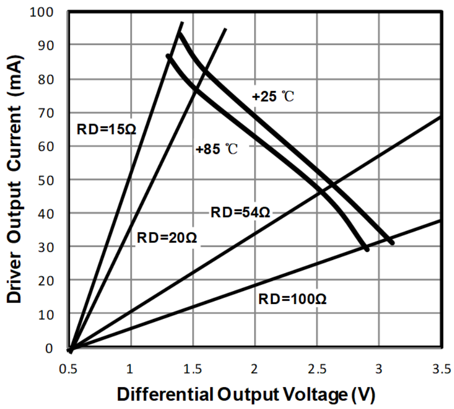


Figure 1. Driver Output Current vs. Differential Output Voltage

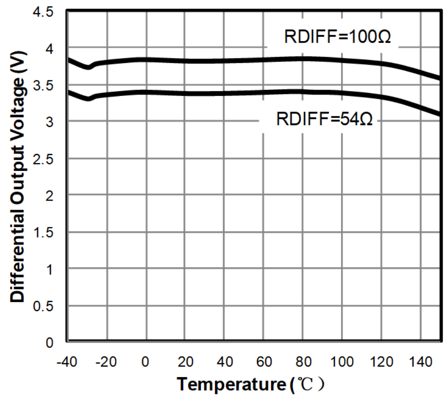


Figure 2. Driver Differential Output Voltage vs. Temperature

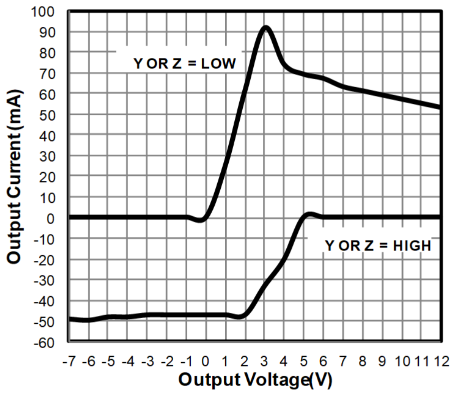


Figure 3. Driver Output Current vs. Short Circuit Voltage

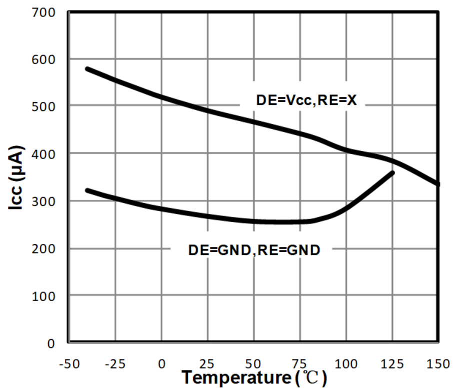


Figure 4. Supply Current vs. Temperature

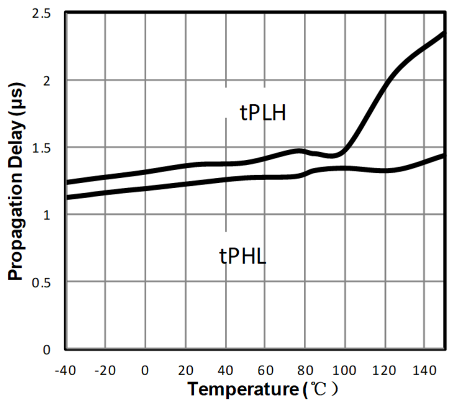


Figure 5. Driver Differential Propagation Delay vs. Temperature

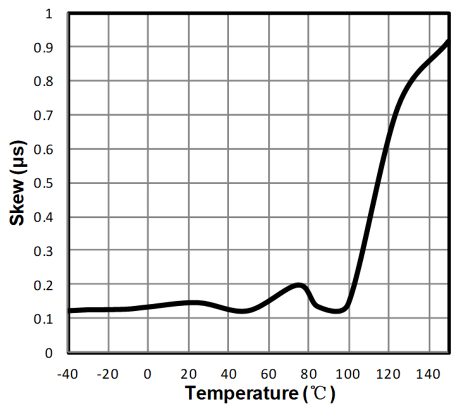


Figure 6. Driver Differential Skew vs. Temperature

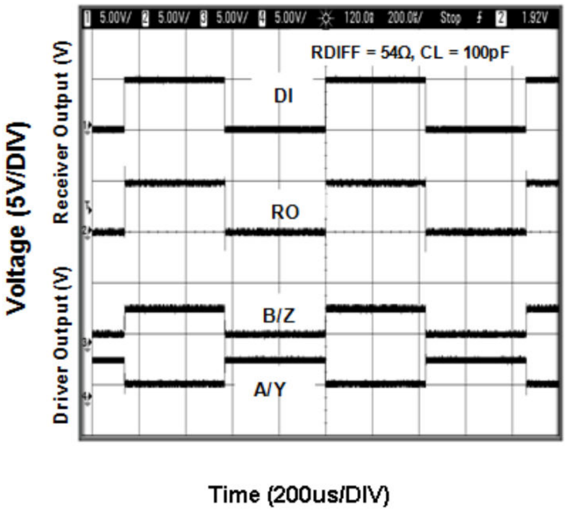


Figure 7. Driver and Receiver Waveforms

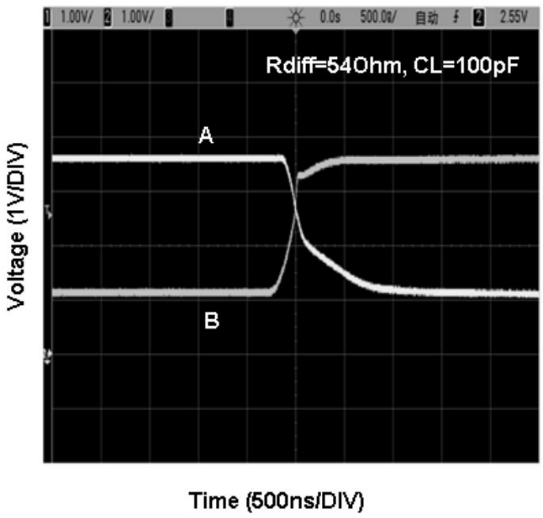


Figure 8. Driver Waveforms

Test Circuits and Waveforms

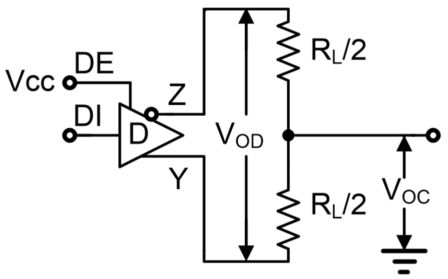


Figure 10A. V_{OD} and V_{OC}

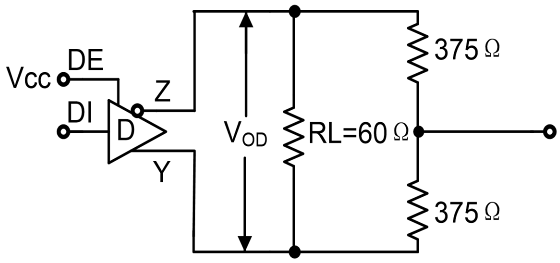


Figure 10B. V_{OD} with Common-Mode Load

Figure 9. DC Driver Test Circuits

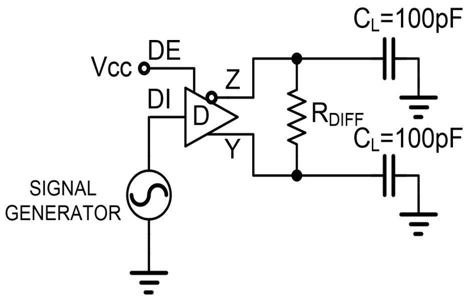


Figure 11A. Test Circuit

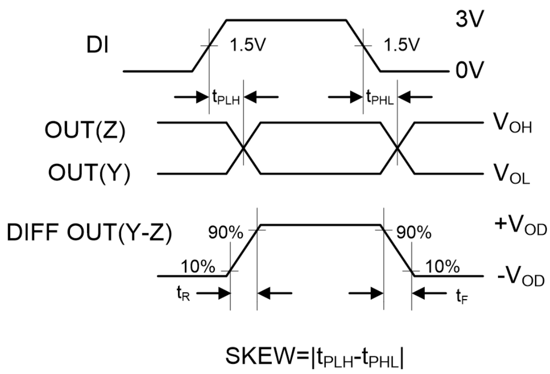
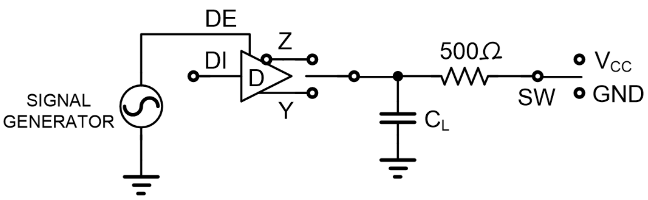


Figure 11B. Measurement Points

Figure 10. 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	V_{CC}	15
tZH	Y/Z	0	1/0	GND	100
tZL	Y/Z	0	0/1	V_{CC}	100
tZH(SHDN)	Y/Z	1	1/0	GND	100
tZL(SHDN)	Y/Z	1	0/1	V_{CC}	100

Figure 12A. Test Circuit

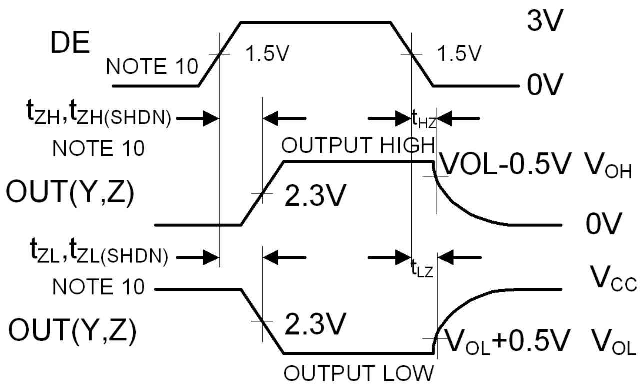


Figure 12B. Measurement Points

Figure 11. Driver Enable and Disable Times

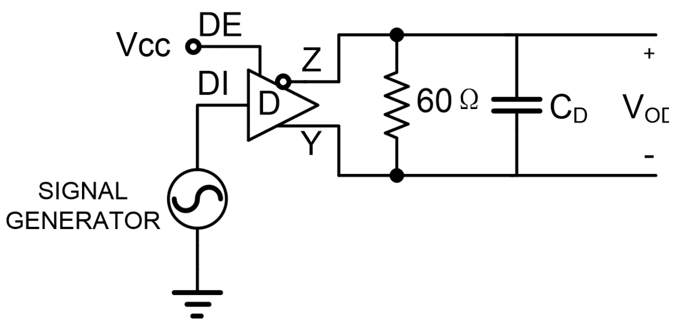


Figure 13A. Test Circuit

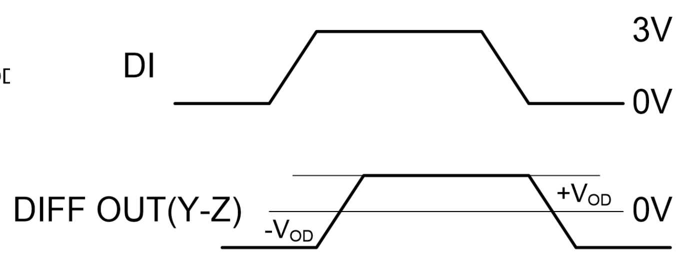


Figure 13B. Measurement Points

Figure 12. Driver Data Rate

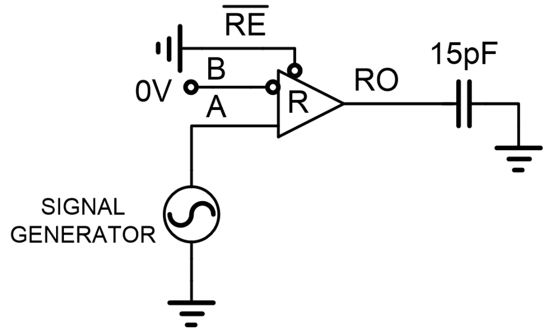


Figure 14A. Test Circuit

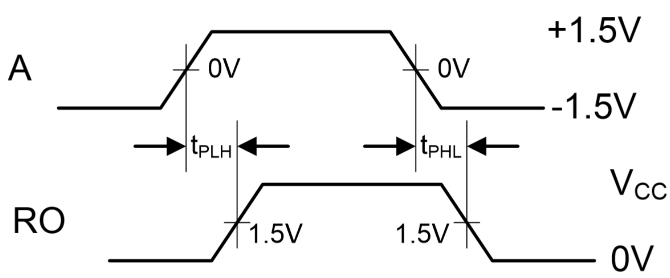
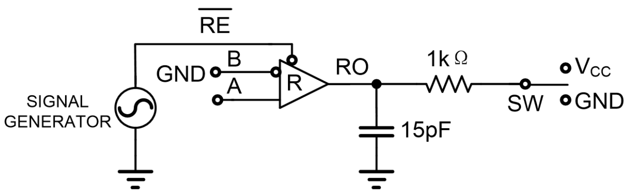


Figure 14B. Measurement Points

Figure 13. Receiver Propagation Delay and Data Rate



PARAMETER	DE	A	SW
tHZ	1	+1.5V	GND
tLZ	1	-1.5V	V_{CC}
tZH	1	+1.5V	GND
tZL	1	-1.5V	V_{CC}
tZH(SHDN)	0	+1.5V	GND
tZL(SHDN)	0	-1.5V	V_{CC}

Figure 15A. Test Circuit

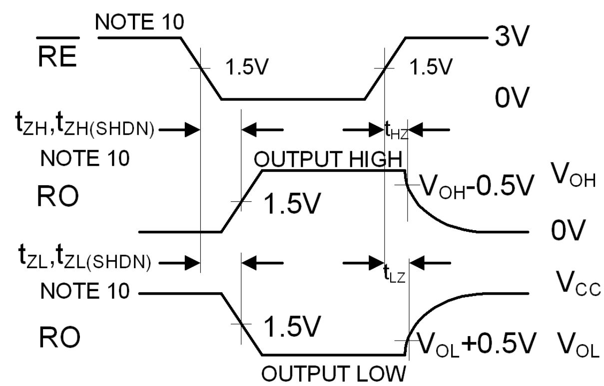


Figure 15B. Measurement Points

Figure 14. Receiver Enable and Disable Times

Detailed Description

Feature Description

RS-485 and RS-422 are differential (balanced) data transmission standards used for long haul or noisy environments. RS-422 is a subset of RS-485, so RS-485 transceivers are also RS-422 compliant. RS-422 is a point-to-multipoint (multidrop) standard, which allows only one driver and up to 10 (assuming one-unit load devices) receivers on each bus. RS-485 is a true multipoint standard, which allows up to 32 one-unit load devices (any combination of drivers and receivers) on each bus. To allow for multipoint operation, the RS-485 specification requires that drivers handle bus contention without sustaining any damage. Another important advantage of RS-485 is the extended common-mode range (CMR), which specifies that the driver outputs and receiver inputs withstand signals that range from +12 V to −7 V. RS-422 and RS-485 are intended for runs as long as 4000', so the wide CMR is necessary to handle ground potential differences, as well as voltages induced in the cable by external fields.

Receiver (Rx) Features

The TP8485E devices utilize a differential input receiver for maximum noise immunity and common-mode rejection. Input sensitivity is better than ±200 mV, as required by the RS-422 and RS-485 specifications. Rx outputs feature high drive levels (typically 25 mA @ V_{OL} = 1 V) to ease the design of optically coupled isolated interfaces. Receiver input resistance of 100 kΩ surpasses the RS-422 specification of 4 kΩ, and is eight times the RS-485 "Unit Load (UL)" requirement of 12-kΩ minimum. Thus, these products are known as "one-eighth UL" transceivers, and there can be up to 256 of these devices on a network while still complying with the RS-485 loading specification. Rx inputs function with common-mode voltages as great as ±7 V outside the power supplies (i.e., +12 V and −7 V), making them ideal for long networks where induced voltages are a realistic concern. 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 drivers, and all receiver outputs are three-stable via the active low $\overline{RE}$ input.

Driver (Tx) Features

The TP8485E drivers are differential output devices that deliver at least 2.5 V across a 54-Ω load (RS-485), and at least 2.8 V across a 100-Ω load (RS-422). The drivers feature low propagation delay skew to maximize bit width and minimize EMI, and all drivers are three-stable via the active high DE input.

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 drivers, and all receiver outputs are three-stable via the active low $\overline{RE}$ input.

Hot Plug Function

When a piece of equipment powers up, there is a period of time when the processor or ASIC driving the RS-485 control lines (DE, $\overline{RE}$) 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 TP8485E 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 $\overline{RE}$, if V_{CC} is less than ~2.5 V. This gives the processor/ASIC a chance to stabilize and drive the RS-485 control lines to a proper state.

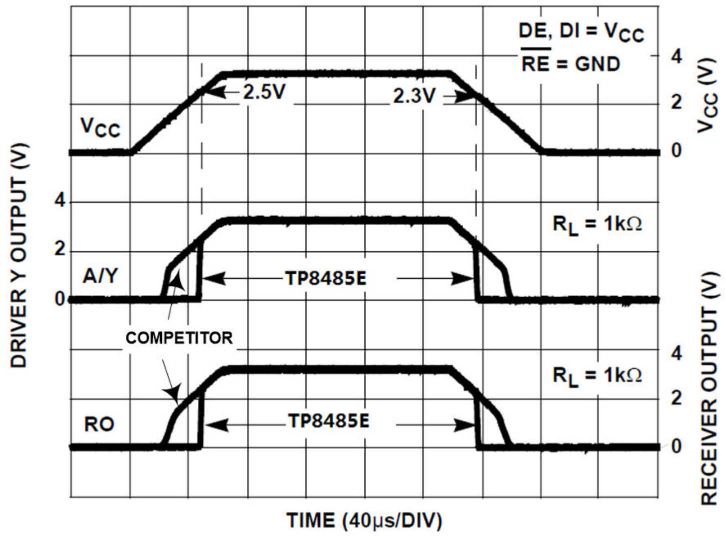


Figure 15. Hot Plug Performance (TP8485E) vs. Competitor without Hot Plug Circuitry

Transient Protection

The bus terminals of the TP8485E transceiver family possess on-chip ESD protection against ±12-kV HBM. The International Electrotechnical Commission (IEC) ESD test is far more severe than the HBM ESD test. The IEC model, featuring a 50% higher charge capacitance (C_S) and a 78% lower discharge resistance (R_D), produces 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.

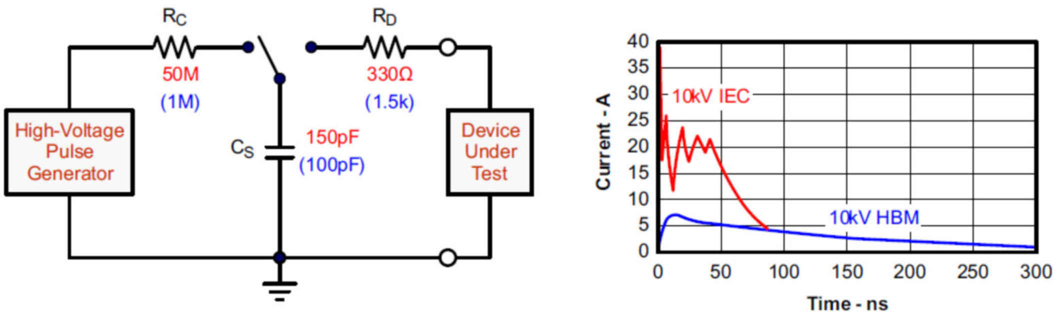


Figure 16. HBM and IEC-ESD Models and Currents in Comparison (HBM Values in Parenthesis)

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 can implement protection against longer-duration transients, typically referred to as surge transients. Figure 16 suggests two circuit designs providing protection against short and long-duration surge transients, in addition to ESD and electrical fast transients (EFTs). Table 4 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 or indirect strikes which induce voltages and currents), or from 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 17 compares the pulse power of EFTs and surge transients with the power caused by an IEC-ESD transient. In the left diagram of Figure 17, 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 right diagram of Figure 17 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.

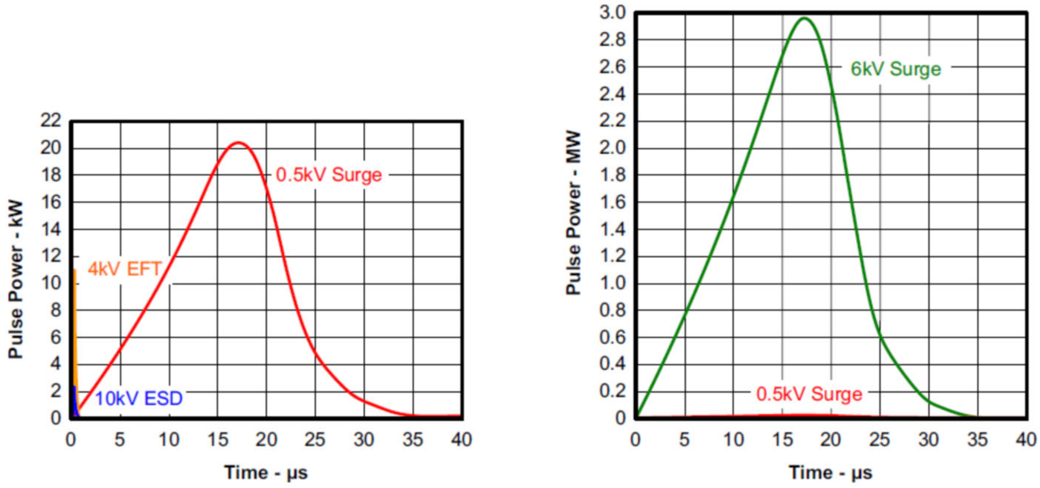


Figure 17. Power Comparison of ESD, EFT, and Surge Transients

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 18 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.

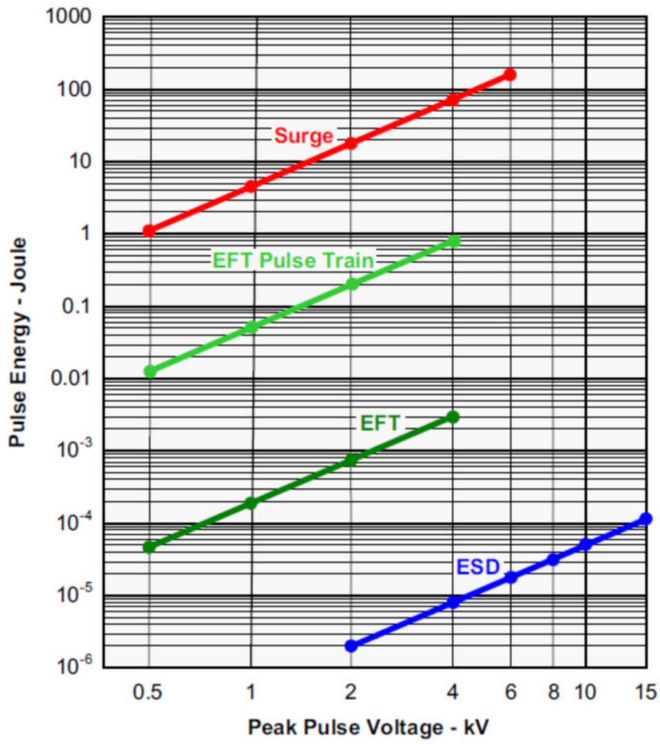


Figure 18. Comparison of Transient Energies

Table 4. Bill of Materials

Device	Function	Order Number	Manufacturer
485	5-V, 250-kbps RS-485 Transceiver	TP8485E	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	200-mA Transient Blocking Unit 200-V, Metal- Oxide Varistor	MOV-10D201K	Bourns

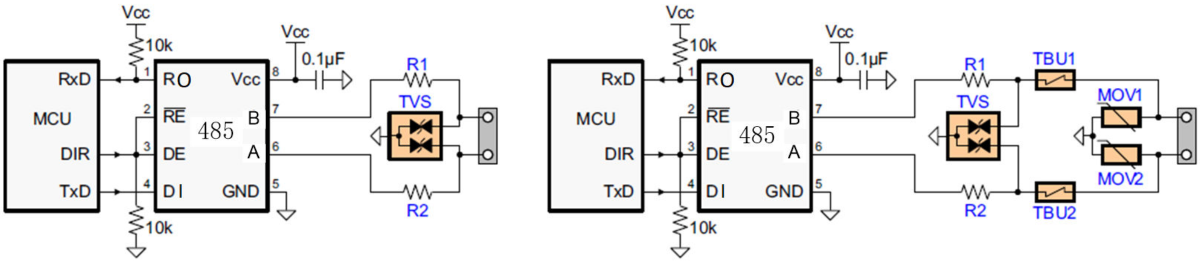
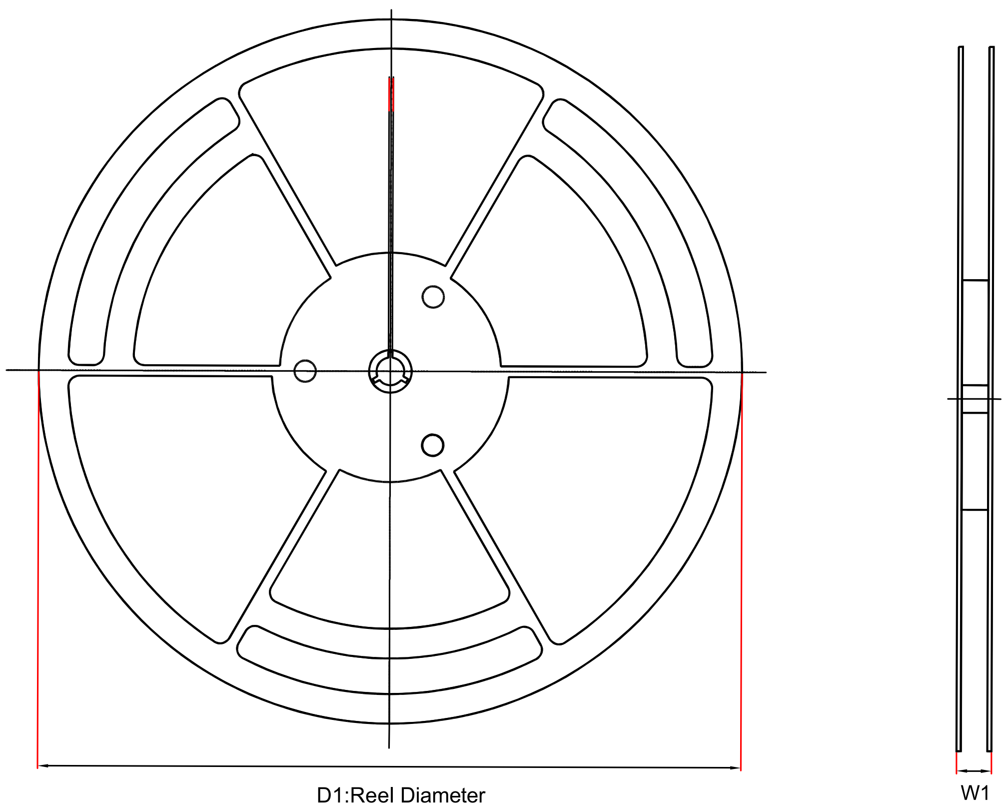
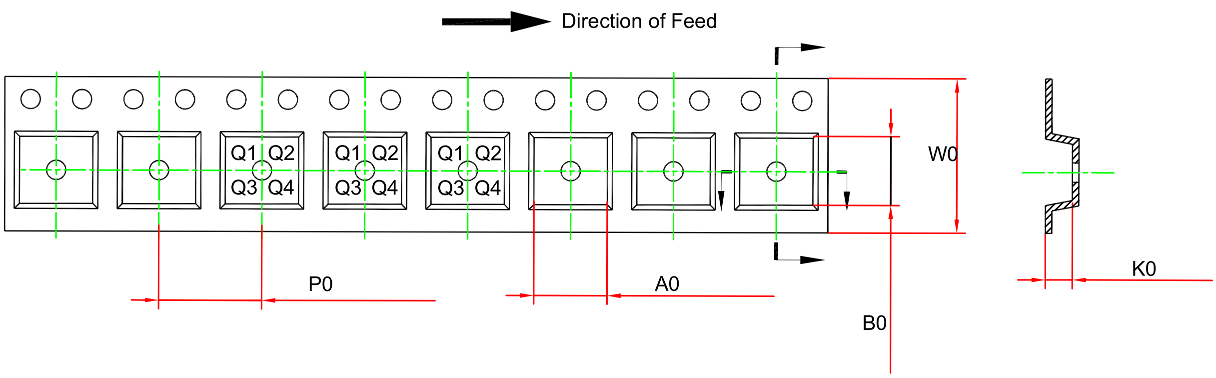


Figure 19. Transient Protections against ESD, EFT, and Surge Transients

The left circuit shown in Figure 19 provides surge protection of ≥ 500-V transients, while the right protection circuit can withstand surge transients of 5 kV.

Tape and Reel Information





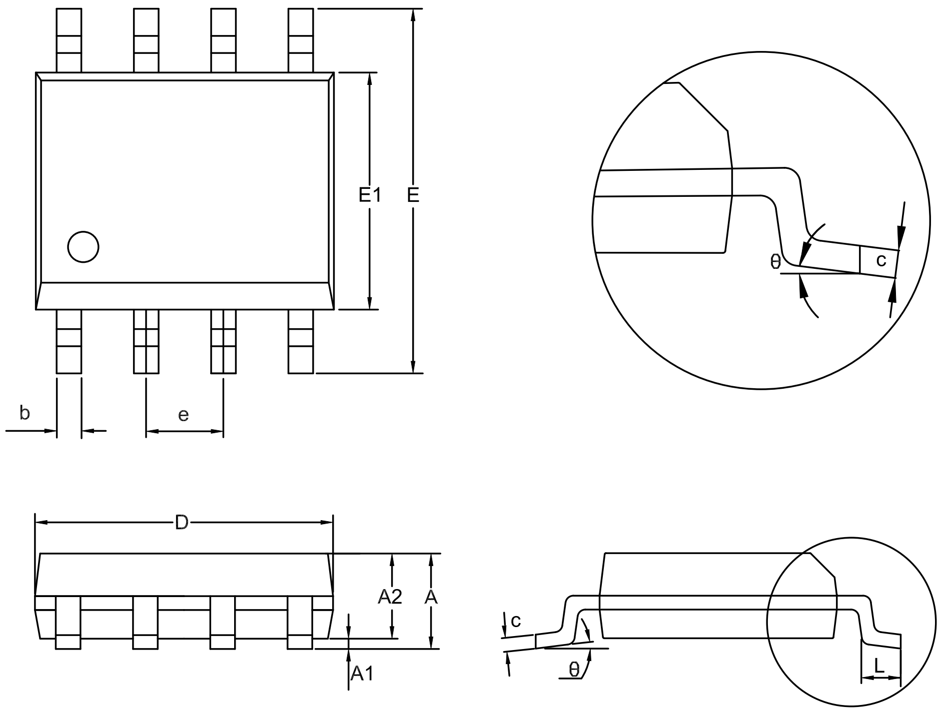
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TP8485E-SR	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TP8485E-VR	MSOP8	330	17.6	5.3	3.4	1.3	8	12	Q1

(1) The value is for reference only. Contact the 3PEAK factory for more information.

Package Outline Dimensions

SOP8

Package Outline Dimensions SO1(SOP-8-A)



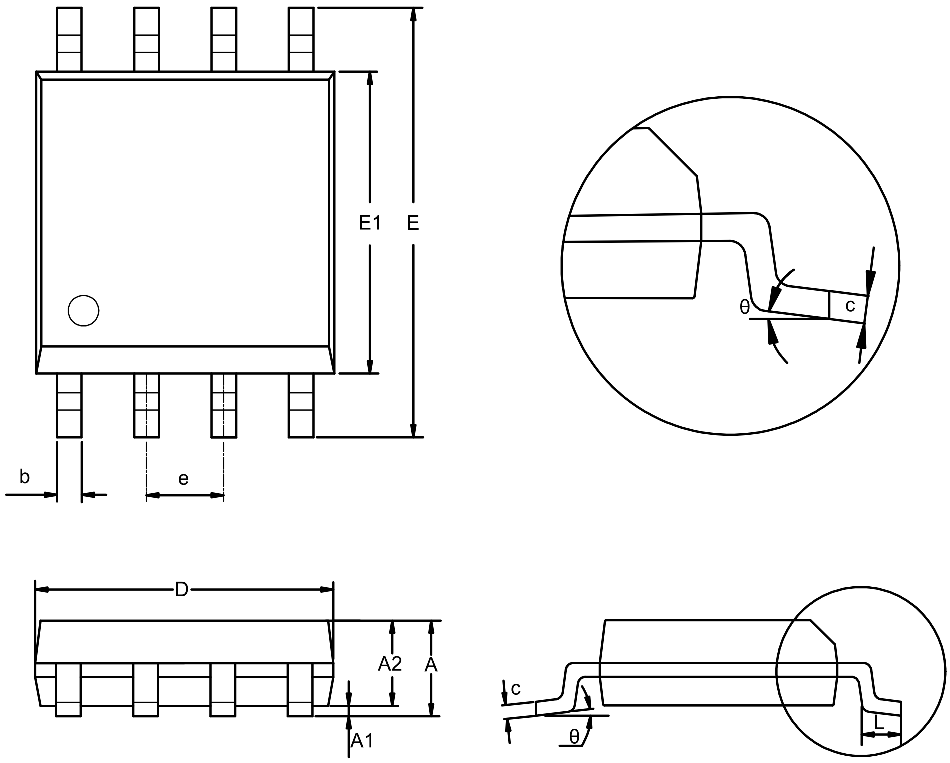
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.000	0.016	0.039
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

MSOP8

Package Outline Dimensions VS1(MSOP-8-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TP8485E-SR	−40 to 125°C	SOP8	TP8485E	3	Tape and Reel, 4,000	Green
TP8485E-VR	−40 to 125°C	MSOP8	8485E	3	Tape and Reel, 3,000	Green

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

IMPORTANT NOTICE AND DISCLAIMER