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±12K 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, Terminated) Receivers**
- **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:**
  – ±12 kV HBM protection

Applications

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

Description

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

Transmitters in this family deliver exceptional differential output voltages (2.5V min/5Vcc), into the RS-485 required 54Ω load, for better noise immunity, or to allow up to eight 120Ω 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 25mA @ VOL = 1V (to ease the design of optocoupled isolated interfaces).

The TP8485E is available in an SOIC-8 and MSOP-8 package, and is characterized from –40°C to 125°C.

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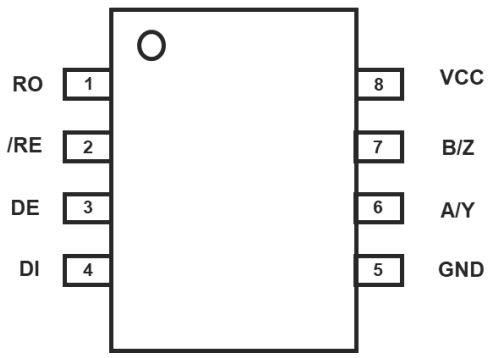
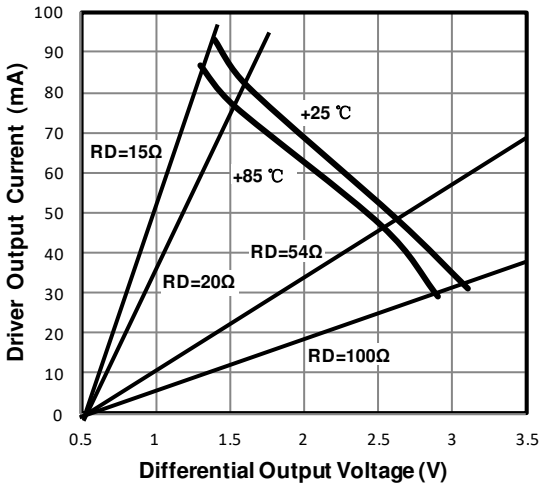
Pin Configuration (Top View)

TP8485E-SR/VR
SOP8/MSOP8



Exceptional Tx Drives Up To 256 Loads While Still Delivering 2.5V VOD



Revision History

Date	Revision	Notes
2015/10/9	Rev. 0	Production release Version 0
2015/12/7	Rev. C	Updated package information
2018/10/22	Rev. D	Updated HBM ESD level
2020/7/20	Rev. E	Updated typo of pinout name
2023/5/10	Rev. E.1	Updated typo of Recommended Operating Conditions

Order Information

Model Name	Order Number	Package	Transport Media, Quantity	Marking Information
TP8485E	TP8485E-SR	8-Pin SOIC	Tape and Reel, 4,000	TP8485E
TP8485E	TP8485E-VR	8-Pin MSOP	Tape and Reel, 3,000	TP8485E

PINOUT DEFINITION

PIN NO.	PIN NAME	I/O	DESCRIPTION
1	RO	Digital output	Receiver Output.
2	/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	Noninverting Receiver Input A and Noninverting Driver Output A.
7	B/Z	Bus input/output	Inverting Receiver Input B and Inverted Driver Output B.
8	VCC	Power	Power Supply.

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

RECEIVER PIN FUNCTIONS

DIFFERENTIAL INPUT	ENABLE	OUTPUT	DESCRIPTION
$V_{ID} = V_A - V_B$	/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

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..... -9V to +14V

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~5.5V

Temperature Range.....-40°C to +125°C

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

Thermal Resistance, ΘJA (Typical)

8-Pin SOIC Package .....158°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 (±25V 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	2.1	2.5		
		RL = 54 Ω with V_A or V_B from –7 to +12 V, V_{CC} = 3V (RS-485)		1	1.5		
		RL = 100 Ω(RS-422)			3		
$\Delta\|V_{OD}\|$	Change in magnitude of driver differential-output voltage	RL = 54 Ω, CL=50 pF, V_{CC} = 5V	See Figure 1A	-0.2	-0.002	0.2	V
$V_{OC(SS)}$	Steady-stage common-mode output voltage	Center of two 27 Ω load resistors	See Figure 1A		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	DI, DE, $\overline{RE}$		2			V
V_{IL}	Logic Input Low Voltage	DI, 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
I_I	Driver input, driver enable and receiver enable input current			-2	0.01	2	μA
I_{OZ}	Receiver high-impedance output current	VO = 0 V or VCC, /RE at VCC		-2	0.01	2	μA
$\|I_{OS}\|$	Driver short-circuit output current	$\|I_{OS}\|$ with V_A or V_B from –7 to +12 V		75	80	115	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		100	150	μA
			VI= -7 V	-150	-80		
I_{CC}	Supply current(quiescent)	Driver and receiver enabled	DE = V_{CC}, /RE = GND, No LOAD		695	900	μA
		Driver enabled, receiver disabled	DE = V_{CC}, /RE = V_{CC}, No LOAD		270	350	
		Driver disabled, receiver enabled	DE = GND, /RE = V_{CC}, No LOAD		480	600	
		Driver and receiver disabled	DE = GND, /RE = V_{CC}, DI= V_{cc} No LOAD		1.4	5	

Switching Characteristics

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							
t_r, t_f	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}, t_{PZH}	Receiver enable time	Driver enabled	See Figure 6		70		ns
		Driver disabled	See Figure 6		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

Test Circuits and Waveforms

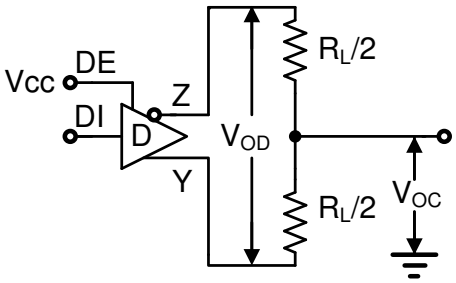


FIGURE 1A. VOD AND VOC

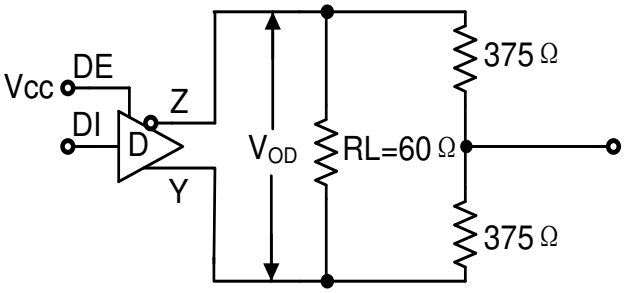


FIGURE 1B. VOD WITH COMMON MODE LOAD

FIGURE 1. DC DRIVER TEST CIRCUITS

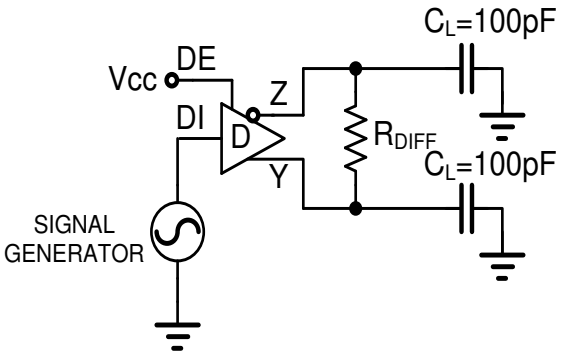


FIGURE 2A. TEST CIRCUIT

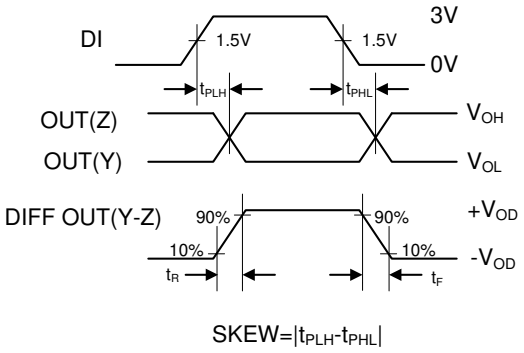
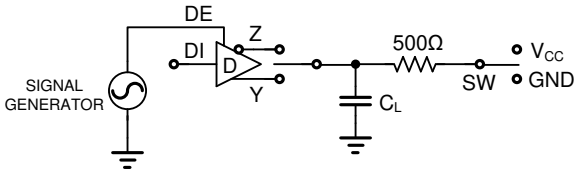


FIGURE 2B. MEASUREMENT POINTS

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	1/0	GND	100
tZL	Y/Z	0	0/1	VCC	100
tZH(SHDN)	Y/Z	1	1/0	GND	100
tZL(SHDN)	Y/Z	1	0/1	VCC	100

FIGURE 3A. TEST CIRCUIT

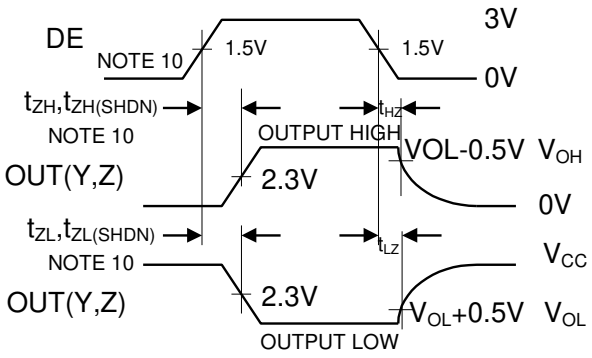


FIGURE 3B. MEASUREMENT POINTS

FIGURE 3. DRIVER ENABLE AND DISABLE TIMES

Test Circuits and Waveforms(continue)

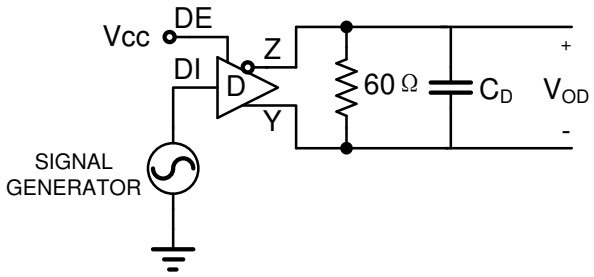


FIGURE 4A. TEST CIRCUIT

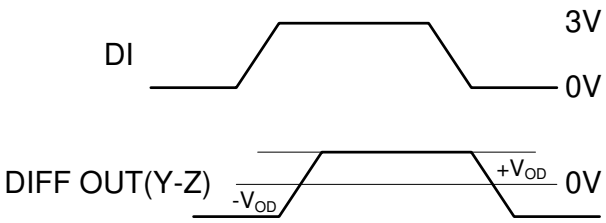


FIGURE 4B. MEASUREMENT POINTS

FIGURE 4. DRIVER DATA RATE

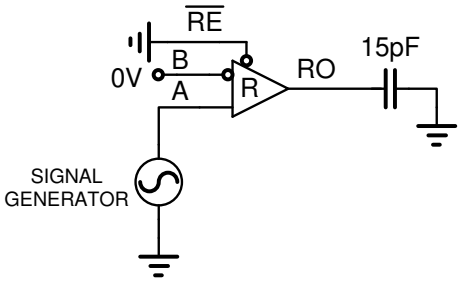


FIGURE 5A. TEST CIRCUIT

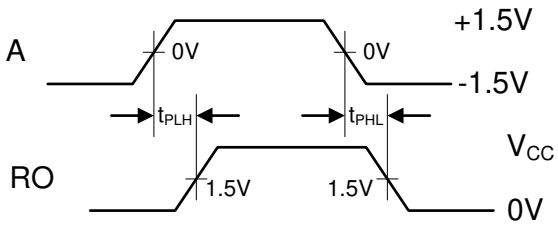
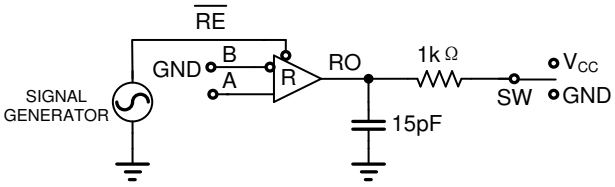


FIGURE 5B. MEASUREMENT POINTS

FIGURE 5. RECEIVER PROPAGATION DELAY AND DATA RATE



PARAMETER	DE	A	SW
tHZ	1	+1.5V	GND
tLZ	1	-1.5V	VCC
tZH	1	+1.5V	GND
tZL	1	-1.5V	VCC
tZH(SHDN)	0	+1.5V	GND
tZL(SHDN)	0	-1.5V	VCC

FIGURE 6A. TEST CIRCUIT

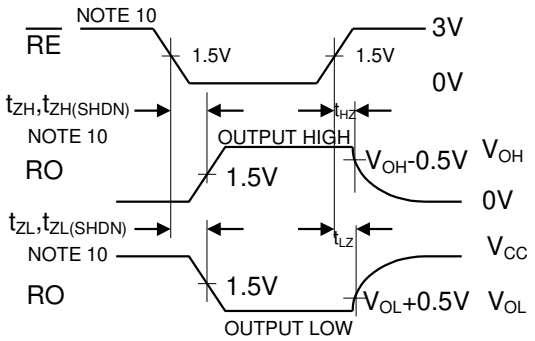


FIGURE 6B. MEASUREMENT POINTS

FIGURE 6. RECEIVER ENABLE AND DISABLE TIMES

Detailed 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 must 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 +12V to -7V. 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

TP8485E utilize a differential input receiver for maximum noise immunity and common mode rejection. Input sensitivity is better than ±200mV, as required by the RS-422 and RS-485 specifications. Rx outputs feature high drive levels (typically 25mA @ V_{OL} = 1V) to ease the design of optically coupled isolated interfaces. Receiver input resistance of 100kΩ surpasses the RS-422 specification of 4kΩ, and is eight times the RS-485 "Unit Load (UL)" requirement of 12kΩ 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 ±7V outside the power supplies (i.e., +12V and -7V), 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 driver, and all receiver outputs are three-stable via the active low RE input.

Driver (Tx) Features

TP8485E driver is a differential output device that delivers at least 2.5V across a 54Ω load (RS-485), and at least 2.8V across a 100Ω load (RS-422). The drivers feature low propagation delay skew to maximize bit width, and to 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 driver, and all receiver outputs are three-statable 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 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 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.

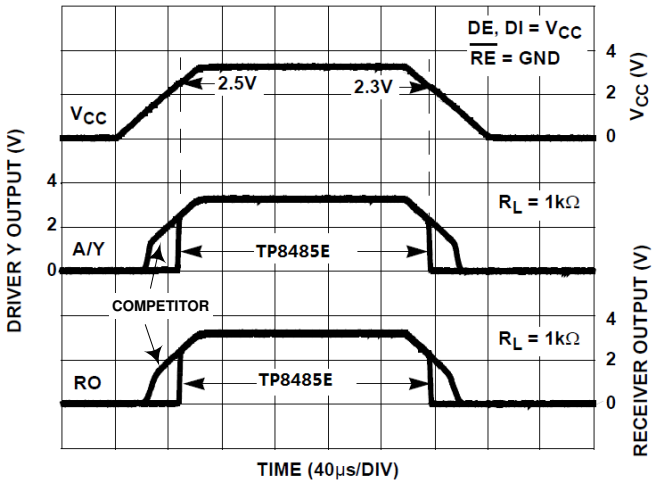


FIGURE 8. HOT PLUG PERFORMANCE (TP8485E) vs Competitor WITHOUT HOT PLUG CIRCUITRY

Transient Protection

The bus terminals of the TP8485E transceiver family possess on-chip ESD protection against ±12kV HBM. The International Electrotechnical Commission (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.

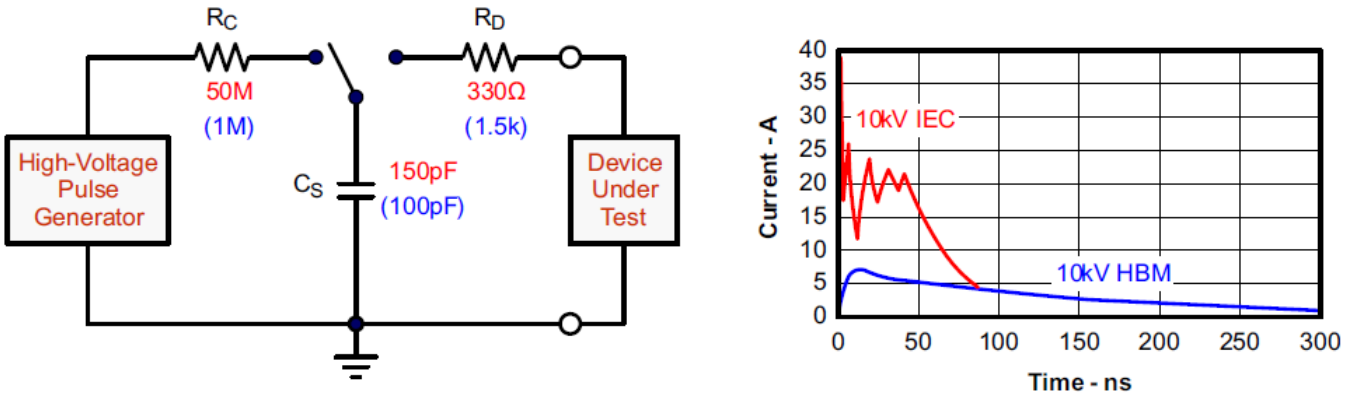


Figure 9. HBM and IEC-ESD Models and Currents in Comparison (HBM Values in Parenthesis)

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.

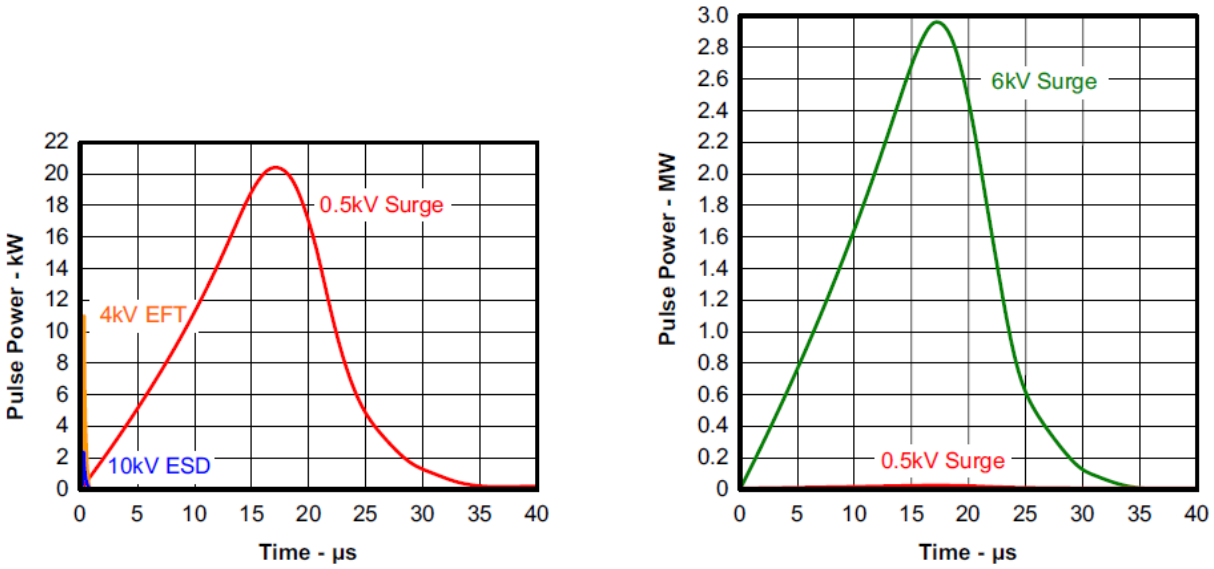


Figure 10. Power Comparison of ESD, EFT, and Surge Transients

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.

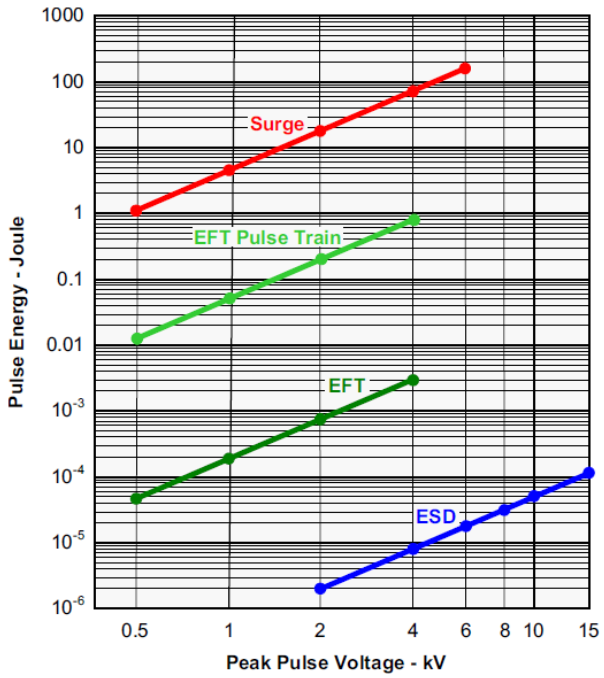


Figure 11. Comparison of Transient Energies

Table 1. Bill of Materials

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

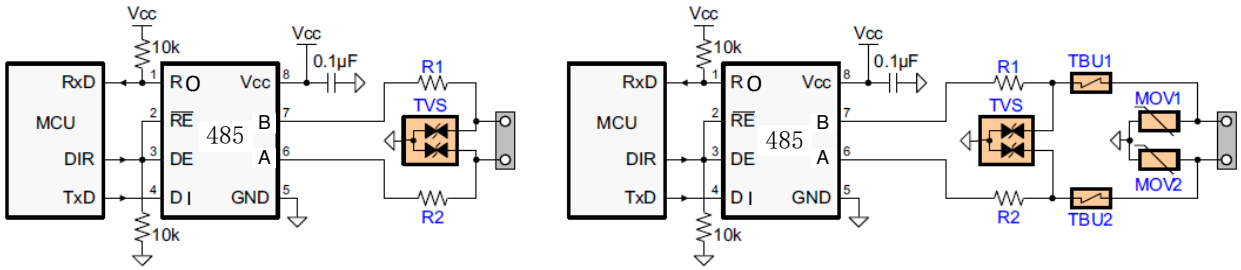


Figure 12. Transient Protections Against ESD, EFT, and Surge Transients

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

VCC = 5V, TA = +25°C; Unless Otherwise Specified.

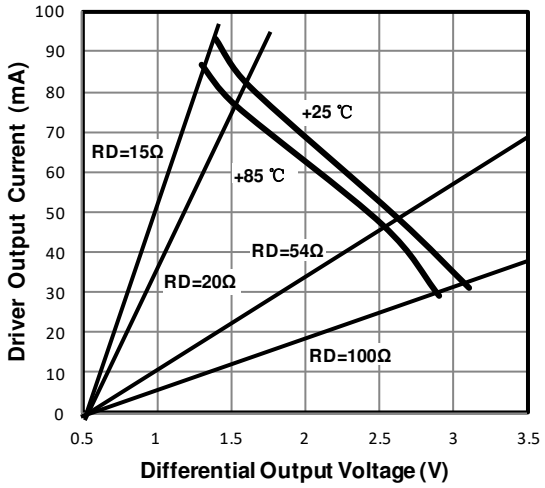


FIGURE 13. DRIVER OUTPUT CURRENT vs OUTPUT VOLTAGE DIFFERENTIAL OUTPUT VOLTAGE

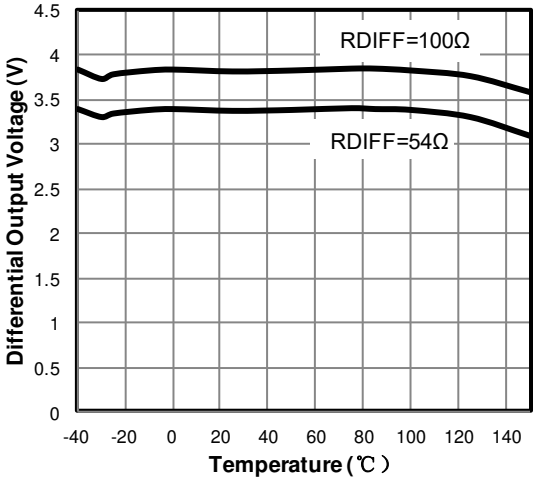


FIGURE 14. DRIVER DIFFERENTIAL vs TEMPERATURE

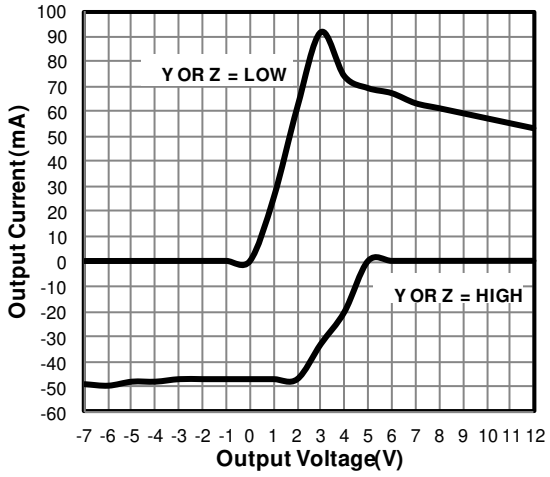


FIGURE 15. DRIVER OUTPUT CURRENT vs SHORT CIRCUIT VOLTAGE

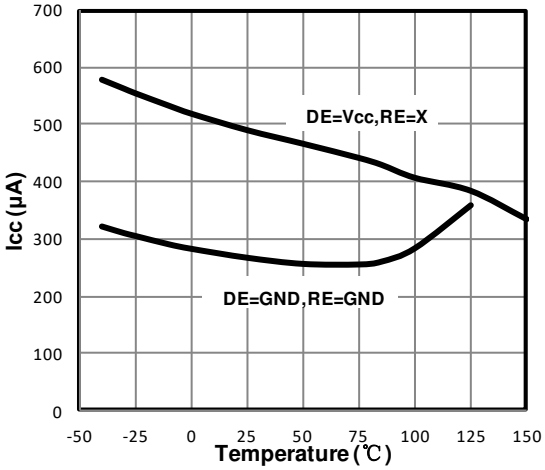


FIGURE 16. SUPPLY CURRENT vs TEMPERATURE

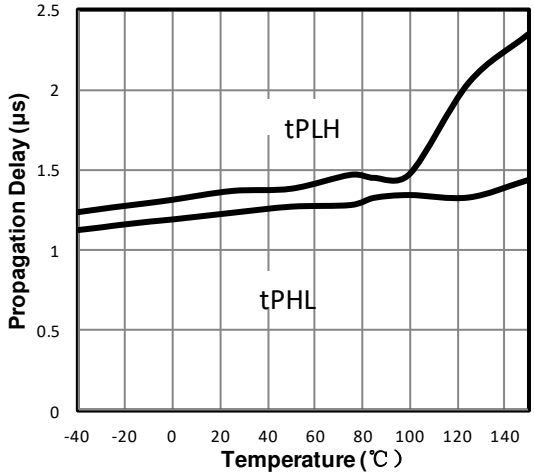


FIGURE 17. DRIVER DIFFERENTIAL PROPAGATION DELAY vs TEMPERATURE

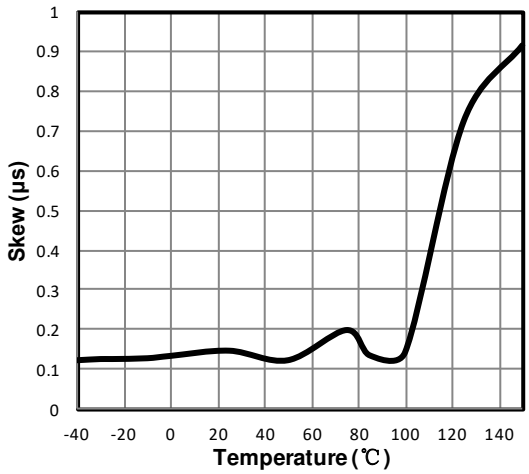


FIGURE 18. DRIVER DIFFERENTIAL SKEW vs TEMPERATURE

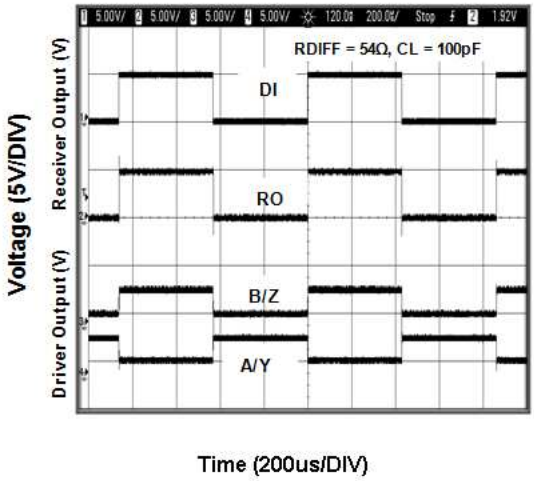


FIGURE 19. DRIVER AND RECEIVER WAVEFORMS

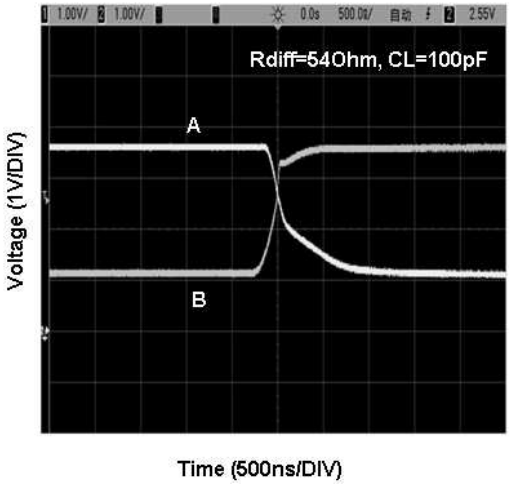
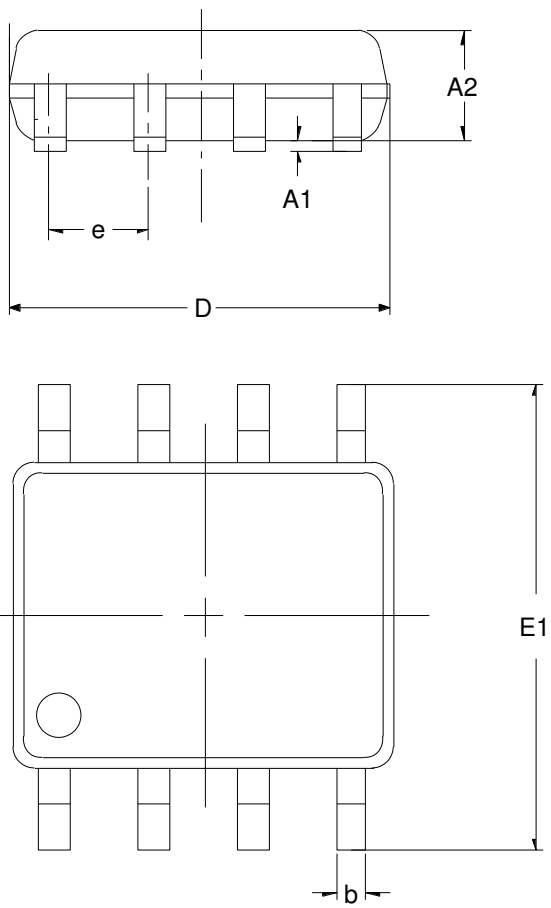


FIGURE 20. DRIVER WAVEFORMS

Package Outline Dimensions

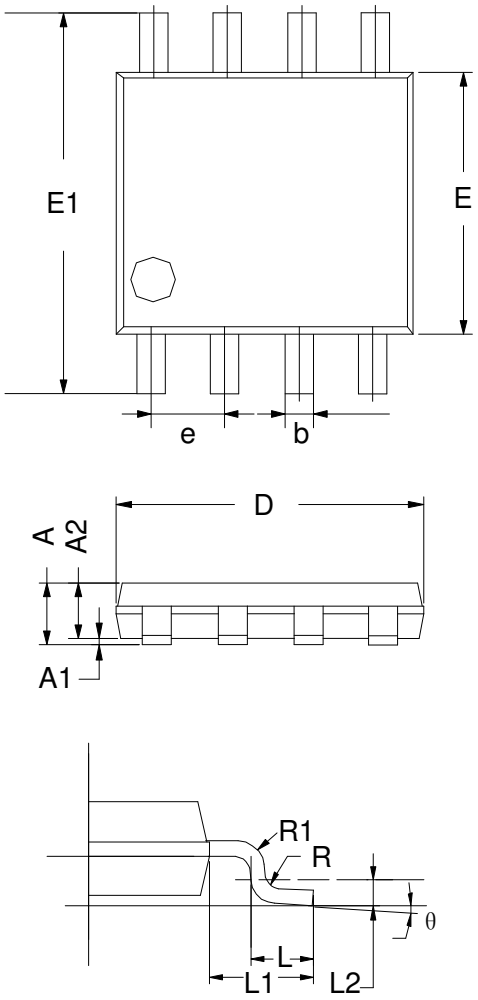
SO-8 (SOIC-8)



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°

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