

±16.5kV ESD (IEC61000-4-2) Protected, Large Output Swing, 5V, Full Fail-Safe, 1/8 Unit Load, RS-485/RS-422 Transceivers

The ISL315XE are BiCMOS, IEC61000 ESD protected, 5V powered, single transceivers that meet both the RS-485 and RS-422 standards for balanced communication. Each driver output and receiver input is protected against ±16.5kV ESD strikes without latch-up.

The ISL315XE transmitters all deliver exceptional differential output voltages (2.4V min), into the RS-485 required 54Ω load, for better noise immunity or to allow up to eight 120Ω terminations in “star” or other non-standard bus topologies.

These devices have very low bus currents (+125μA/-75μA), so they present a true “1/8 unit load” to the RS-485 bus. This allows up to 256 transceivers on the network without violating the RS-485 specification’s 32 unit load maximum, and 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 28mA @ V_{OL} = 1V (to ease the design of optocoupled isolated interfaces).

The ISL3150E, ISL3152E, ISL3153E, ISL3155E utilize slew rate limited drivers which reduce EMI, and minimize reflections from improperly terminated transmission lines, or unterminated stubs in multidrop and multipoint applications.

Hot Plug circuitry ensures that the Tx and Rx outputs remain in a high impedance state until the power supply has stabilized, and the Tx outputs are fully short circuit protected.

The ISL3150E, ISL3153E, ISL3156E are configured for full duplex applications. The half duplex versions multiplex the Rx inputs and Tx outputs to allow transceivers with output disable functions in 8 Ld packages.

Features

- High Driver V_{OD} 2.4V (Min) @ R_D = 54Ω
Better Noise Immunity, or Drive Up to 8 Terminations
- IEC61000 ESD Protection on RS-485 I/O Pins . . . ±16.5kV
- Class 3 ESD Level on all Other Pins >7kV HBM
- Tiny MSOP Packages Save 50% Board Space
- Full Fail-safe (Open, Short, Terminated and Undriven) Receivers
- High Rx I_{OL} to Drive Opto-Couplers for Isolated Applications
- Hot Plug Circuitry - Tx and Rx Outputs Remain Three-State During Power-up/Power-Down
- True 1/8 Unit Load Allows up to 256 Devices on the Bus
- Specified for Single 5V, 10% Tolerance, Supplies
- High Data Rates up to 20Mbps
- Low Quiescent Supply Current 600μA
Ultra Low Shutdown Supply Current 70nA
- -7V to +12V Common Mode Input Voltage Range
- Half and Full Duplex Pinouts
- Pb-Free Packaging (RoHS Compliant)
- Three-State Rx and Tx Outputs
- Current Limiting and Thermal Shutdown for Driver Overload Protection

Applications

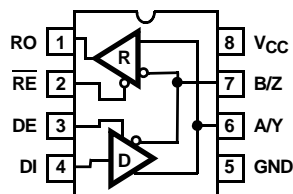
- Utility Meters and Automated Meter Reading Systems
- High Node Count Systems
- PROFIBUS® and Field Bus Networks, and Factory Automation
- Security Camera Networks
- Building Lighting and Environmental Control Systems
- Industrial/Process Control Networks

TABLE 1. SUMMARY OF FEATURES

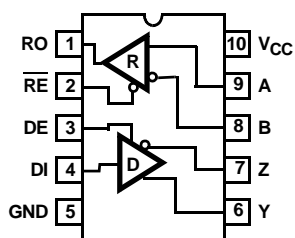
PART NUMBER	HALF/FULL DUPLEX	DATA RATE (Mbps)	SLEW-RATE LIMITED?	HOT PLUG	# DEVICES ON BUS	Rx/Tx ENABLE?	QUIESCENT I _{CC} (μA)	LOW POWER SHUTDOWN?	PIN COUNT
ISL3150E	Full	0.115	Yes	Yes	256	Yes	600	Yes	10, 14
ISL3152E	Half	0.115	Yes	Yes	256	Yes	600	Yes	8
ISL3153E	Full	1	Yes	Yes	256	Yes	600	Yes	10, 14
ISL3155E	Half	1	Yes	Yes	256	Yes	600	Yes	8
ISL3156E	Full	20	No	Yes	256	Yes	600	Yes	10, 14
ISL3158E	Half	20	No	Yes	256	Yes	600	Yes	8

Pinouts

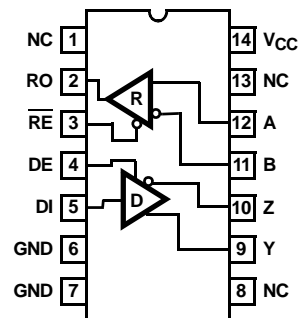
ISL3152E, ISL3155E, ISL3158E
(8 LD MSOP, 8 LD SOIC)
TOP VIEW



ISL3150E, ISL3153E, ISL3156E
(10 LD MSOP)
TOP VIEW



ISL3150E, ISL3153E, ISL3156E
(14 LD SOIC)
TOP VIEW



Ordering Information

PART NUMBER (Notes 1, 2)	PART MARKING	TEMP. RANGE (°C)	PACKAGE	PKG. DWG. #
ISL3150EIBZ	3150EIBZ	-40 to +85	14 Ld SOIC (Pb-free)	M14.15
ISL3150EIUZ	3150Z	-40 to +85	10 Ld MSOP (Pb-free)	M10.118
ISL3152EIBZ	3152EIBZ	-40 to +85	8 Ld SOIC (Pb-free)	M8.15
ISL3152EIUZ	3152Z	-40 to +85	8 Ld MSOP (Pb-free)	M8.118
ISL3153EIBZ	3153EIBZ	-40 to +85	14 Ld SOIC (Pb-free)	M14.15
ISL3153EIUZ	3153Z	-40 to +85	10 Ld MSOP (Pb-free)	M10.118
ISL3155EIBZ	3155EIBZ	-40 to +85	8 Ld SOIC (Pb-free)	M8.15
ISL3155EIUZ	3155Z	-40 to +85	8 Ld MSOP (Pb-free)	M8.118
ISL3156EIBZ	3156EIBZ	-40 to +85	14 Ld SOIC (Pb-free)	M14.15
ISL3156EIUZ	3156Z	-40 to +85	10 Ld MSOP (Pb-free)	M10.118
ISL3158EIBZ	3158EIBZ	-40 to +85	8 Ld SOIC (Pb-free)	M8.15
ISL3158EIUZ	3158Z	-40 to +85	8 Ld MSOP (Pb-free)	M8.118

NOTES:

- Units also available in Tape and Reel; Add "-T" to suffix.
- Intersil Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.

Truth Tables

TRANSMITTING				
INPUTS			OUTPUTS	
\overline{RE}	DE	DI	Z	Y
X	1	1	0	1
X	1	0	1	0
0	0	X	High-Z	High-Z
1	0	X	High-Z *	High-Z *

NOTE: *Shutdown Mode (See Note 9).

RECEIVING				
INPUTS				OUTPUT
\overline{RE}	DE Half Duplex	DE Full Duplex	A-B	RO
0	0	X	$\geq -0.05V$	1
0	0	X	$\leq -0.2V$	0
0	0	X	Inputs Open/Shorted	1
1	0	0	X	High-Z *
1	1	1	X	High-Z

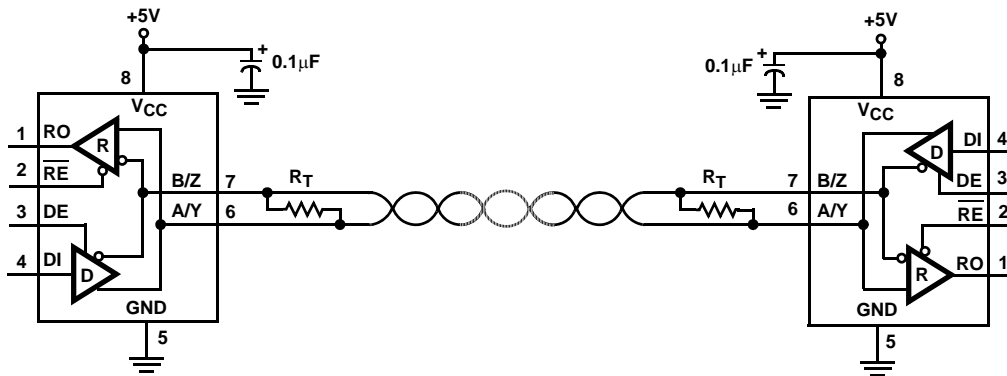
NOTE: *Shutdown Mode (See Note 9).

Pin Descriptions

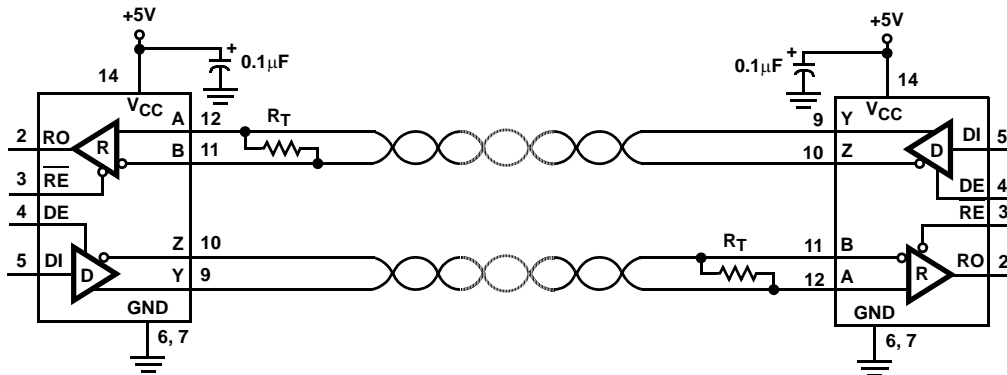
PIN	FUNCTION
RO	Receiver output: If A-B $\geq -50mV$, RO is high; If A-B $\leq -200mV$, RO is low; RO = High if A and B are unconnected (floating) or shorted.
\overline{RE}	Receiver output enable. RO is enabled when \overline{RE} is low; RO is high impedance when \overline{RE} is high.
DE	Driver output enable. The driver outputs, Y and Z, are enabled by bringing DE high. They are high impedance when DE is low.
DI	Driver input. A low on DI forces output Y low and output Z high. Similarly, a high on DI forces output Y high and output Z low.
GND	Ground connection.
A/Y	$\pm 16.5kV$ IEC61000 ESD Protected RS-485/422 level, noninverting receiver input and noninverting driver output. Pin is an input if DE = 0; pin is an output if DE = 1.
B/Z	$\pm 16.5kV$ IEC61000 ESD Protected RS-485/422 level, Inverting receiver input and inverting driver output. Pin is an input if DE = 0; pin is an output if DE = 1.
A	$\pm 16.5kV$ IEC61000 ESD Protected RS-485/422 level, noninverting receiver input.
B	$\pm 16.5kV$ IEC61000 ESD Protected RS-485/422 level, inverting receiver input.
Y	$\pm 16.5kV$ IEC61000 ESD Protected RS-485/422 level, noninverting driver output.
Z	$\pm 16.5kV$ IEC61000 ESD Protected RS-485/422 level, inverting driver output.
V _{CC}	System power supply input (4.5V to 5.5V).
NC	No Connection.

Typical Operating Circuit

ISL3152E, ISL3155E, ISL3158E



ISL3150E, ISL3153E, ISL3156E (SOIC PIN NUMBERS SHOWN)



Absolute Maximum Ratings

V _{CC} to Ground	7V
Input Voltages	
DI, DE, RE	-0.3V to (V _{CC} + 0.3V)
Input/Output Voltages	
A/Y, B/Z, A, B, Y, Z	-9V to +13V
A/Y, B/Z, A, B, Y, Z (Transient Pulse Through 100Ω)	±25V
RO	-0.3V to (V _{CC} + 0.3V)
Short Circuit Duration	
Y, Z	Continuous
ESD Rating	See Specification Table

Thermal Information

Thermal Resistance (Typical, Note 3)	θ _{JA} (°C/W)
8 Ld SOIC Package	105
8 Ld MSOP Package	140
10 Ld MSOP Package	130
14 Ld SOIC Package	130
Maximum Junction Temperature (Plastic Package)	+150°C
Maximum Storage Temperature Range	-65°C to +150°C
Maximum Lead Temperature (Soldering 10s)	+300°C
(Lead Tips Only)	

Operating Conditions

Temperature Range	-40°C to +85°C
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CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

- θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air. See Tech Brief TB379 for details.

Electrical Specifications Test Conditions: V_{CC} = 4.5V to 5.5V; Unless Otherwise Specified. Typical values are at V_{CC} = 5V, T_A = +25°C (Note 4)

PARAMETER	SYMBOL	TEST CONDITIONS	TEMP (°C)	MIN	TYP	MAX	UNITS	
DC CHARACTERISTICS								
Driver Differential V _{OUT} (No load)	V _{OD1}		Full	-	-	V _{CC}	V	
Driver Differential V _{OUT} (Loaded)	V _{OD2}	R _L = 100Ω (RS-422) (Figure 1A)	Full	2.8	3.6	-	V	
		R _L = 54Ω (RS-485) (Figure 1A)	Full	2.4	3.1	V _{CC}	V	
		R _L = 15Ω (Eight 120Ω terminations) (Note 13)	25	-	1.65	-	V	
		R _L = 60Ω, -7V ≤ V _{CM} ≤ 12V (Figure 1B)	Full	2.4	3	-	V	
Change in Magnitude of Driver Differential V _{OUT} for Complementary Output States	ΔV _{OD}	R _L = 54Ω or 100Ω (Figure 1A)	Full	-	0.01	0.2	V	
Driver Common-Mode V _{OUT}	V _{OC}	R _L = 54Ω or 100Ω (Figure 1A)	Full	-	-	3.15	V	
Change in Magnitude of Driver Common-Mode V _{OUT} for Complementary Output States	ΔV _{OC}	R _L = 54Ω or 100Ω (Figure 1A)	Full	-	0.01	0.2	V	
Logic Input High Voltage	V _{IH}	DE, DI, RE	Full	2	-	-	V	
Logic Input Low Voltage	V _{IL}	DE, DI, RE	Full	-	-	0.8	V	
DI Input Hysteresis Voltage	V _{HYS}		25	-	100	-	mV	
Logic Input Current	I _{IN1}	DE, DI, RE	Full	-2	-	2	μA	
Input Current (A, B, A/Y, B/Z)	I _{IN2}	DE = 0V, V _{CC} = 0V or 5.5V	V _{IN} = 12V	Full	-	70	125	μA
			V _{IN} = -7V	Full	-75	55	-	μA
Output Leakage Current (Y, Z) (Full Duplex Versions Only)	I _{IN3}	RE = 0V, DE = 0V, V _{CC} = 0V or 5.5V	V _{IN} = 12V	Full	-	1	40	μA
			V _{IN} = -7V	Full	-40	-9	-	μA
Output Leakage Current (Y, Z) in Shutdown Mode (Full Duplex)	I _{IN4}	RE = V _{CC} , DE = 0V, V _{CC} = 0V or 5.5V	V _{IN} = 12V	Full	-	1	20	μA
			V _{IN} = -7V	Full	-20	-9	-	μA
Driver Short-Circuit Current, V _O = High or Low	I _{OSD1}	DE = V _{CC} , -7V ≤ V _Y or V _Z ≤ 12V (Note 6)	Full	-	-	±250	mA	
Receiver Differential Threshold Voltage	V _{TH}	-7V ≤ V _{CM} ≤ 12V	Full	-200	-90	-50	mV	

ISL3150E, ISL3152E, ISL3153E, ISL3155E, ISL3156E, ISL3158E

Electrical Specifications Test Conditions: $V_{CC} = 4.5V$ to $5.5V$; Unless Otherwise Specified. Typical values are at $V_{CC} = 5V$, $T_A = +25^\circ C$ (Note 4) **(Continued)**

PARAMETER	SYMBOL	TEST CONDITIONS	TEMP (°C)	MIN	TYP	MAX	UNITS	
Receiver Input Hysteresis	ΔV_{TH}	$V_{CM} = 0V$	25	-	20	-	mV	
Receiver Output High Voltage	V_{OH}	$I_O = -8mA$, $V_{ID} = -50mV$	Full	$V_{CC} - 1.2$	4.3	-	V	
Receiver Output Low Voltage	V_{OL}	$I_O = -8mA$, $V_{ID} = -200mV$	Full	-	0.25	0.4	V	
Receiver Output Low Current	I_{OL}	$V_O = 1V$, $V_{ID} = -200mV$	Full	20	28	-	mA	
Three-State (high impedance) Receiver Output Current	I_{OZR}	$0.4V \leq V_O \leq 2.4V$	Full	-1	0.03	1	μA	
Receiver Input Resistance	R_{IN}	$-7V \leq V_{CM} \leq 12V$	Full	96	160	-	$k\Omega$	
Receiver Short-Circuit Current	I_{OSR}	$0V \leq V_O \leq V_{CC}$	Full	± 7	65	± 85	mA	
SUPPLY CURRENT								
No-Load Supply Current (Note 5)	I_{CC}	Half Duplex Versions, $DE = V_{CC}$, $\overline{RE} = X$, $DI = 0V$ or V_{CC}	Full	-	650	800	μA	
		All Versions, $DE = 0V$, $\overline{RE} = 0V$, or Full Duplex Versions, $DE = V_{CC}$, $\overline{RE} = X$. $DI = 0V$ or V_{CC}	Full	-	550	700	μA	
Shutdown Supply Current	I_{SHDN}	$DE = 0V$, $\overline{RE} = V_{CC}$, $DI = 0V$ or V_{CC}	Full	-	0.07	3	μA	
ESD PERFORMANCE								
RS-485 Pins (A, Y, B, Z, A/Y, B/Z)		IEC61000-4-2, Air-Gap Discharge Method	1/2 Duplex	25	-	± 16.5	-	kV
			Full Duplex	25	-	± 10	-	kV
			IEC61000-4-2, Contact Discharge Method	25	-	± 9	-	kV
			Human Body Model, From Bus Pins to GND	25	-	± 16.5	-	kV
All Pins		HBM, per MIL-STD-883 Method 3015	25	-	± 7	-	kV	
		MM	25	-	400	-	V	
DRIVER SWITCHING CHARACTERISTICS (115kbps Versions; ISL3150E, ISL3152E)								
Driver Differential Output Delay	t_{PLH} , t_{PHL}	$R_{DIFF} = 54\Omega$, $C_L = 100pF$ (Figure 2)	Full	500	970	1300	ns	
Driver Differential Output Skew	t_{SKEW}	$R_{DIFF} = 54\Omega$, $C_L = 100pF$ (Figure 2)	Full	-	12	50	ns	
Driver Differential Rise or Fall Time	t_R , t_F	$R_{DIFF} = 54\Omega$, $C_L = 100pF$ (Figure 2)	Full	700	1100	1600	ns	
Maximum Data Rate	f_{MAX}	$C_D = 820pF$ (Figure 4, Note 12)	Full	115	2000	-	kbps	
Driver Enable to Output High	t_{ZH}	$R_L = 500\Omega$, $C_L = 100pF$, $SW = GND$ (Figure 3), (Note 7)	Full	-	300	600	ns	
Driver Enable to Output Low	t_{ZL}	$R_L = 500\Omega$, $C_L = 100pF$, $SW = V_{CC}$ (Figure 3), (Note 7)	Full	-	130	500	ns	
Driver Disable from Output Low	t_{LZ}	$R_L = 500\Omega$, $C_L = 15pF$, $SW = V_{CC}$ (Figure 3)	Full	-	50	65	ns	
Driver Disable from Output High	t_{HZ}	$R_L = 500\Omega$, $C_L = 15pF$, $SW = GND$ (Figure 3)	Full	-	35	60	ns	
Time to Shutdown	t_{SHDN}	(Notes 9, 12)	Full	60	160	600	ns	
Driver Enable from Shutdown to Output High	$t_{ZH(SHDN)}$	$R_L = 500\Omega$, $C_L = 100pF$, $SW = GND$ (Figure 3), (Notes 9, 10)	Full	-	-	250	ns	
Driver Enable from Shutdown to Output Low	$t_{ZL(SHDN)}$	$R_L = 500\Omega$, $C_L = 100pF$, $SW = V_{CC}$ (Figure 3), (Notes 9, 10)	Full	-	-	250	ns	
DRIVER SWITCHING CHARACTERISTICS (1Mbps Versions; ISL3153E, ISL3155E)								
Driver Differential Output Delay	t_{PLH} , t_{PHL}	$R_{DIFF} = 54\Omega$, $C_L = 100pF$ (Figure 2)	Full	150	270	400	ns	
Driver Differential Output Skew	t_{SKEW}	$R_{DIFF} = 54\Omega$, $C_L = 100pF$ (Figure 2)	Full	-	3	10	ns	

ISL3150E, ISL3152E, ISL3153E, ISL3155E, ISL3156E, ISL3158E

Electrical Specifications Test Conditions: $V_{CC} = 4.5V$ to $5.5V$; Unless Otherwise Specified. Typical values are at $V_{CC} = 5V$, $T_A = +25^\circ C$
(Note 4) **(Continued)**

PARAMETER	SYMBOL	TEST CONDITIONS	TEMP (°C)	MIN	TYP	MAX	UNITS
Driver Differential Rise or Fall Time	t_R, t_F	$R_{DIFF} = 54\Omega, C_L = 100pF$ (Figure 2)	Full	150	325	450	ns
Maximum Data Rate	f_{MAX}	$C_D = 820pF$ (Figure 4, Note 12)	Full	1	8	-	Mbps
Driver Enable to Output High	t_{ZH}	$R_L = 500\Omega, C_L = 100pF, SW = GND$ (Figure 3), (Note 7)	Full	-	110	200	ns
Driver Enable to Output Low	t_{ZL}	$R_L = 500\Omega, C_L = 100pF, SW = V_{CC}$ (Figure 3), (Note 7)	Full	-	60	200	ns
Driver Disable from Output Low	t_{LZ}	$R_L = 500\Omega, C_L = 15pF, SW = V_{CC}$ (Figure 3)	Full	-	50	65	ns
Driver Disable from Output High	t_{HZ}	$R_L = 500\Omega, C_L = 15pF, SW = GND$ (Figure 3)	Full	-	35	60	ns
Time to Shutdown	t_{SHDN}	(Notes 9, 12)	Full	60	160	600	ns
Driver Enable from Shutdown to Output High	$t_{ZH}(SHDN)$	$R_L = 500\Omega, C_L = 100pF, SW = GND$ (Figure 3), (Notes 9, 10)	Full	-	-	250	ns
Driver Enable from Shutdown to Output Low	$t_{ZL}(SHDN)$	$R_L = 500\Omega, C_L = 100pF, SW = V_{CC}$ (Figure 3), (Notes 9, 10)	Full	-	-	250	ns

DRIVER SWITCHING CHARACTERISTICS (20Mbps Versions; ISL3156E, ISL3158E)

Driver Differential Output Delay	t_{PLH}, t_{PHL}	$R_{DIFF} = 54\Omega, C_L = 100pF$ (Figure 2)	Full	-	21	30	ns
Driver Differential Output Skew	t_{SKEW}	$R_{DIFF} = 54\Omega, C_L = 100pF$ (Figure 2)	Full	-	0.2	3	ns
Driver Differential Rise or Fall Time	t_R, t_F	$R_{DIFF} = 54\Omega, C_L = 100pF$ (Figure 2)	Full	-	12	16	ns
Maximum Data Rate	f_{MAX}	$C_D = 470pF$ (Figure 4, Note 12)	Full	20	55	-	Mbps
Driver Enable to Output High	t_{ZH}	$R_L = 500\Omega, C_L = 100pF, SW = GND$ (Figure 3), (Note 7)	Full	-	30	45	ns
Driver Enable to Output Low	t_{ZL}	$R_L = 500\Omega, C_L = 100pF, SW = V_{CC}$ (Figure 3), (Note 7)	Full	-	28	45	ns
Driver Disable from Output Low	t_{LZ}	$R_L = 500\Omega, C_L = 15pF, SW = V_{CC}$ (Figure 3)	Full	-	50	65	ns
Driver Disable from Output High	t_{HZ}	$R_L = 500\Omega, C_L = 15pF, SW = GND$ (Figure 3)	Full	-	38	60	ns
Time to Shutdown	t_{SHDN}	(Notes 9, 12)	Full	60	160	600	ns
Driver Enable from Shutdown to Output High	$t_{ZH}(SHDN)$	$R_L = 500\Omega, C_L = 100pF, SW = GND$ (Figure 3), (Notes 9, 10)	Full	-	-	200	ns
Driver Enable from Shutdown to Output Low	$t_{ZL}(SHDN)$	$R_L = 500\Omega, C_L = 100pF, SW = V_{CC}$ (Figure 3), (Notes 9, 10)	Full	-	-	200	ns

RECEIVER SWITCHING CHARACTERISTICS (115kbps and 1Mbps Versions; ISL3150E through ISL3155E)

Maximum Data Rate	f_{MAX}	(Figure 5, Note 12)	Full	1	12	-	Mbps
Receiver Input to Output Delay	t_{PLH}, t_{PHL}	(Figure 5)	Full	-	100	150	ns
Receiver Skew $t_{PLH} - t_{PHL}$	t_{SKD}	(Figure 5)	Full	-	4	10	ns
Receiver Enable to Output Low	t_{ZL}	$R_L = 1k\Omega, C_L = 15pF, SW = V_{CC}$ (Figure 6), (Note 8)	Full	-	9	20	ns
Receiver Enable to Output High	t_{ZH}	$R_L = 1k\Omega, C_L = 15pF, SW = GND$ (Figure 6), (Note 8)	Full	-	7	20	ns
Receiver Disable from Output Low	t_{LZ}	$R_L = 1k\Omega, C_L = 15pF, SW = V_{CC}$ (Figure 6)	Full	-	8	15	ns
Receiver Disable from Output High	t_{HZ}	$R_L = 1k\Omega, C_L = 15pF, SW = GND$ (Figure 6)	Full	-	8	15	ns
Time to Shutdown	t_{SHDN}	(Notes 9, 12)	Full	60	160	600	ns
Receiver Enable from Shutdown to Output High	$t_{ZH}(SHDN)$	$R_L = 1k\Omega, C_L = 15pF, SW = GND$ (Figure 6), (Notes 9, 11)	Full	-	-	200	ns

ISL3150E, ISL3152E, ISL3153E, ISL3155E, ISL3156E, ISL3158E

Electrical Specifications Test Conditions: $V_{CC} = 4.5V$ to $5.5V$; Unless Otherwise Specified. Typical values are at $V_{CC} = 5V$, $T_A = +25^\circ C$ (Note 4) **(Continued)**

PARAMETER	SYMBOL	TEST CONDITIONS	TEMP (°C)	MIN	TYP	MAX	UNITS
Receiver Enable from Shutdown to Output Low	$t_{ZL}(SHDN)$	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = V_{CC}$ (Figure 6), (Notes 9, 11)	Full	-	-	200	ns
RECEIVER SWITCHING CHARACTERISTICS (20Mbps Versions; ISL3156E, ISL3158E)							
Maximum Data Rate	f_{MAX}	(Figure 5, Note 12)	Full	20	30	-	Mbps
Receiver Input to Output Delay	t_{PLH} , t_{PHL}	(Figure 5)	Full	-	33	45	ns
Receiver Skew $t_{PLH} - t_{PHL}$	t_{SKD}	(Figure 5)	Full	-	2.5	5	ns
Receiver Enable to Output Low	t_{ZL}	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = V_{CC}$ (Figure 6), (Note 8)	Full	-	8	15	ns
Receiver Enable to Output High	t_{ZH}	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = GND$ (Figure 6), (Note 8)	Full	-	7	15	ns
Receiver Disable from Output Low	t_{LZ}	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = V_{CC}$ (Figure 6)	Full	-	8	15	ns
Receiver Disable from Output High	t_{HZ}	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = GND$ (Figure 6)	Full	-	8	15	ns
Time to Shutdown	t_{SHDN}	(Notes 9, 12)	Full	60	160	600	ns
Receiver Enable from Shutdown to Output High	$t_{ZH}(SHDN)$	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = GND$ (Figure 6), (Notes 9, 11)	Full	-	-	200	ns
Receiver Enable from Shutdown to Output Low	$t_{ZL}(SHDN)$	$R_L = 1k\Omega$, $C_L = 15pF$, $SW = V_{CC}$ (Figure 6), (Notes 9, 11)	Full	-	-	200	ns

NOTES:

- All currents into device pins are positive; all currents out of device pins are negative. All voltages are referenced to device ground unless otherwise specified.
- Supply current specification is valid for loaded drivers when $DE = 0V$.
- Applies to peak current. See "Typical Performance Curves" for more information.
- Keep $\overline{RE} = 0$ to prevent the device from entering SHDN.
- The \overline{RE} signal high time must be short enough (typically $<100ns$) to prevent the device from entering SHDN.
- Transceivers are put into shutdown by bringing \overline{RE} high and DE low. If the inputs are in this state for less than 60ns, the parts are guaranteed not to enter shutdown. If the inputs are in this state for at least 600ns, the parts are guaranteed to have entered shutdown. See "Low-Power Shutdown Mode" section.
- Keep $\overline{RE} = V_{CC}$, and set the DE signal low time $>600ns$ to ensure that the device enters SHDN.
- Set the \overline{RE} signal high time $>600ns$ to ensure that the device enters SHDN.
- Guaranteed by characterization but not tested.
- See Figure 8 for more information, and for performance over temperature.

Test Circuits and Waveforms

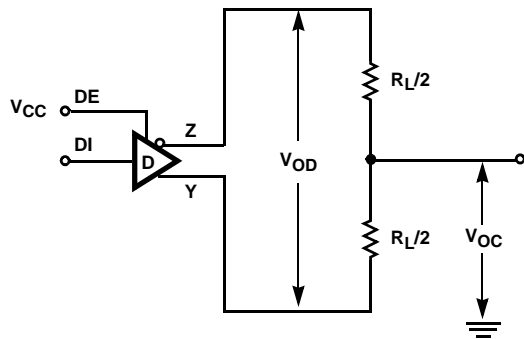


FIGURE 1A. V_{OD} AND V_{OC}

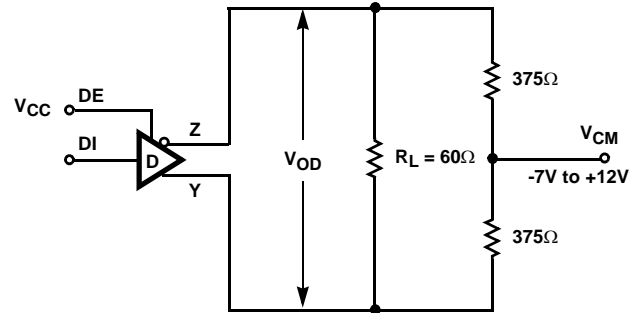


FIGURE 1B. V_{OD} WITH COMMON MODE LOAD

FIGURE 1. DC DRIVER TEST CIRCUITS

Test Circuits and Waveforms (Continued)

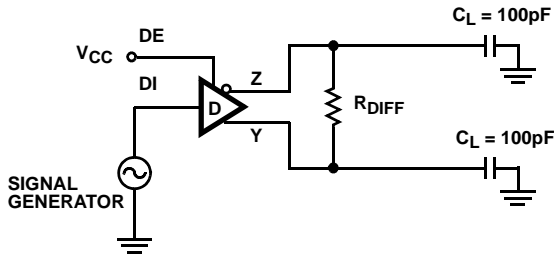


FIGURE 2A. TEST CIRCUIT

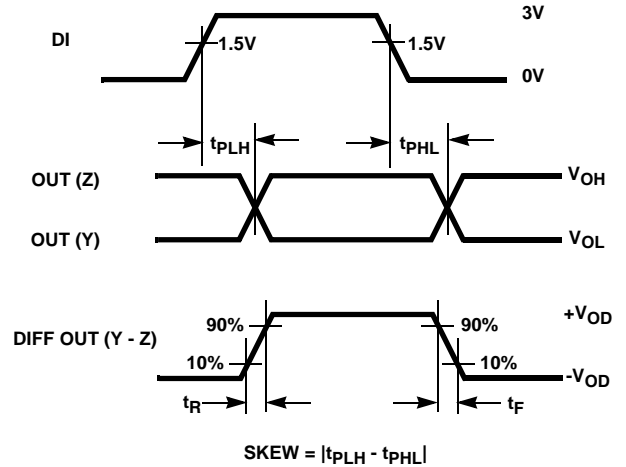
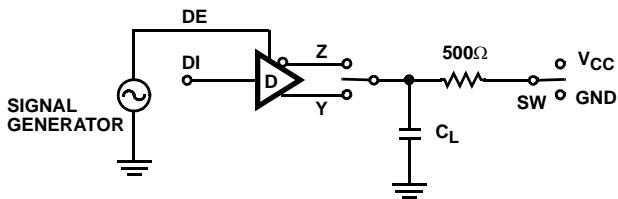


FIGURE 2B. MEASUREMENT POINTS

FIGURE 2. DRIVER PROPAGATION DELAY AND DIFFERENTIAL TRANSITION TIMES



PARAMETER	OUTPUT	RE	DI	SW	CL (pF)
t _{HZ}	Y/Z	X	1/0	GND	15
t _{LZ}	Y/Z	X	0/1	V _{CC}	15
t _{ZH}	Y/Z	0 (Note 7)	1/0	GND	100
t _{ZL}	Y/Z	0 (Note 7)	0/1	V _{CC}	100
t _{ZH(SHDN)}	Y/Z	1 (Note 10)	1/0	GND	100
t _{ZL(SHDN)}	Y/Z	1 (Note 10)	0/1	V _{CC}	100

FIGURE 3A. TEST CIRCUIT

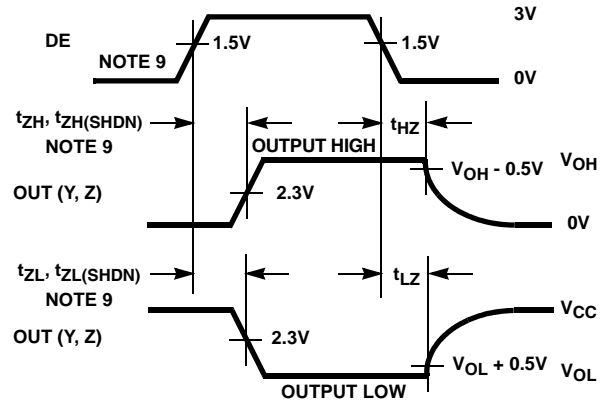


FIGURE 3B. MEASUREMENT POINTS

FIGURE 3. DRIVER ENABLE AND DISABLE TIMES

Test Circuits and Waveforms (Continued)

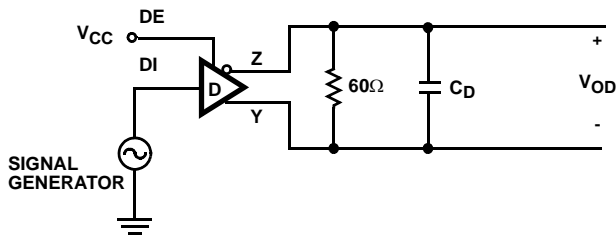


FIGURE 4A. TEST CIRCUIT

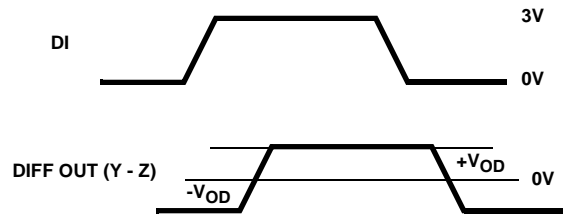


FIGURE 4B. MEASUREMENT POINTS

FIGURE 4. DRIVER DATA RATE

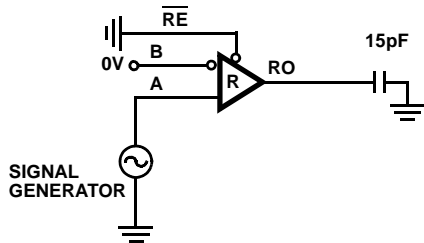


FIGURE 5A. TEST CIRCUIT

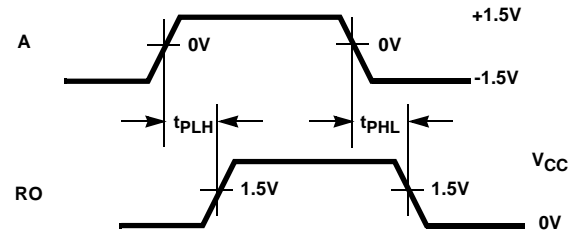


FIGURE 5B. MEASUREMENT POINTS

FIGURE 5. RECEIVER PROPAGATION DELAY AND DATA RATE

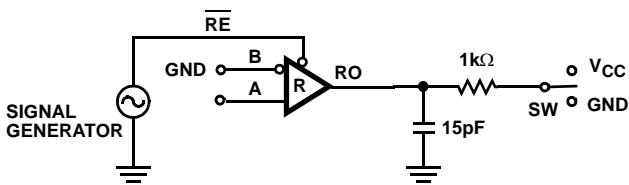


FIGURE 6A. TEST CIRCUIT

PARAMETER	DE	A	SW
t_{HZ}	0	+1.5V	GND
t_{LZ}	0	-1.5V	V_{CC}
t_{ZH} (Note 8)	0	+1.5V	GND
t_{ZL} (Note 8)	0	-1.5V	V_{CC}
$t_{ZH(SHDN)}$ (Note 11)	0	+1.5V	GND
$t_{ZL(SHDN)}$ (Note 11)	0	-1.5V	V_{CC}

FIGURE 6. RECEIVER ENABLE AND DISABLE TIMES

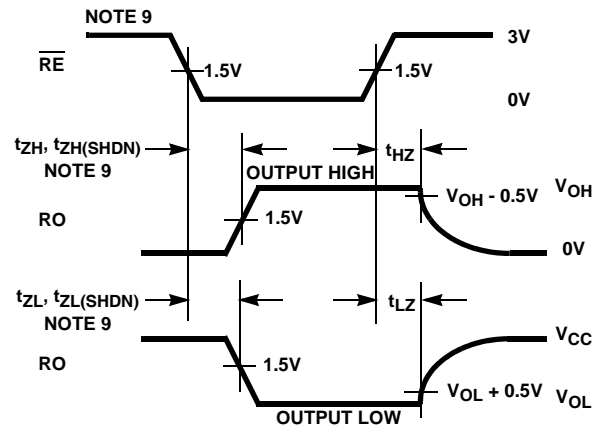


FIGURE 6B. MEASUREMENT POINTS

Application Information

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 spec 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

These devices utilize a differential input receiver for maximum noise immunity and common mode rejection. Input sensitivity is better than $\pm 200\text{mV}$, as required by the RS-422 and RS-485 specifications.

Rx outputs feature high drive levels - typically 28mA @ $V_{OL} = 1\text{V}$ (to ease the design of optically coupled isolated interfaces).

Receiver input resistance of 96k Ω surpasses the RS-422 spec of 4k Ω , and is eight times the RS-485 "Unit Load (UL)" requirement of 12k Ω 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 spec.

Rx inputs function with common mode voltages as great as $\pm 7\text{V}$ 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-statable via the active low $\overline{\text{RE}}$ input.

Driver (Tx) Features

The RS-485/422 driver is a differential output device that delivers at least 2.4V across a 54 Ω load (RS-485), and at least 2.8V across a 100 Ω load (RS-422). The drivers feature low propagation delay skew to maximize bit width, and to minimize EMI, and all drivers are three-statable via the active high DE input.

The 115kbps and 1Mbps driver outputs are slew rate limited to minimize EMI, and to minimize reflections in unterminated or improperly terminated networks. Outputs of the ISL3156E and ISL3158E drivers are not limited, so faster output transition times allow data rates of at least 20Mbps

High V_{OD} Improves Noise Immunity and Flexibility

The ISL315XE driver design delivers larger differential output voltages (V_{OD}) than the RS-485 standard requires, or than most RS-485 transmitters can deliver. The minimum $\pm 2.4\text{V}$ V_{OD} guarantees at least $\pm 900\text{mV}$ more noise immunity than networks built using standard 1.5V V_{OD} transmitters.

Another advantage of the large V_{OD} is the ability to drive more than two bus terminations, which allows for utilizing the ISL315XE in "star" and other multi-terminated, "non-standard" network topologies. Figure 8, details the transmitter's V_{OD} vs. I_{OUT} characteristic, and includes load lines for six (20 Ω) and eight (15 Ω) 120 Ω terminations. The figure shows that the driver typically delivers 1.65/1.5V into 6/8 terminations, even at the worst case temperature of +85°C. The RS-485 standard requires a minimum 1.5V V_{OD} into two terminations, but the ISL315XE delivers RS-485 voltage levels with 3X to 4X the number of terminations.

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 ($\overline{\text{DE}}$, $\overline{\text{RE}}$) 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 ISL315XE 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 $\overline{\text{DE}}$ and $\overline{\text{RE}}$, if V_{CC} is less than $\sim 3.4\text{V}$. This gives the processor/ASIC a chance to stabilize and drive the RS-485 control lines to the proper states.

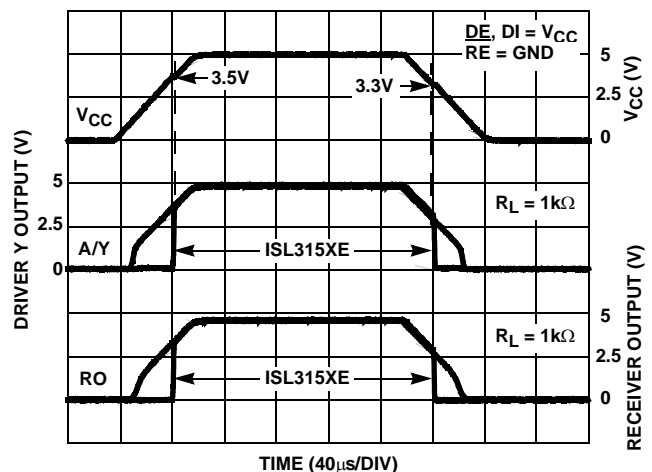


FIGURE 7. HOT PLUG PERFORMANCE (ISL315XE) vs ISL83088E WITHOUT HOT PLUG CIRCUITRY

ESD Protection

All pins on these devices include class 3 (>7kV) 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 $\pm 16.5\text{kV}$ HBM and $\pm 16.5\text{kV}$ (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.

IEC61000-4-2 Testing

The IEC61000 test method applies to finished equipment, rather than to an individual IC. Therefore, the pins most likely to suffer an ESD event are those that are exposed to the outside world (the RS-485 pins in this case), and the IC is tested in its typical application configuration (power applied) rather than testing each pin-to-pin combination. The IEC61000 standard's lower current limiting resistor coupled with the larger charge storage capacitor yields a test that is much more severe than the HBM test. The extra ESD protection built into this device's RS-485 pins allows the design of equipment meeting level 4 criteria without the need for additional board level protection on the RS-485 port.

AIR-GAP DISCHARGE TEST METHOD

For this test method, a charged probe tip moves toward the IC pin until the voltage arcs to it. The current waveform delivered to the IC pin depends on approach speed, humidity, temperature, etc., so it is difficult to obtain repeatable results. The ISL315XE 1/2 duplex RS-485 pins withstand $\pm 16.5\text{kV}$ air-gap discharges.

CONTACT DISCHARGE TEST METHOD

During the contact discharge test, the probe contacts the tested pin before the probe tip is energized, thereby eliminating the variables associated with the air-gap discharge. The result is a more repeatable and predictable test, but equipment limits prevent testing devices at voltages higher than $\pm 9\text{kV}$. The RS-485 pins of all the ISL315XE versions survive $\pm 9\text{kV}$ contact discharges.

Data Rate, Cables, and Terminations

RS-485/422 are intended for network lengths up to 4000', but the maximum system data rate decreases as the transmission length increases. Devices operating at 20Mbps are limited to lengths less than 100', while the 115kbps versions can operate at full data rates with lengths of several thousand feet.

Twisted pair is the cable of choice for RS-485/422 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 receivers in these ICs.

Proper termination is imperative, when using the 20Mbps devices, to minimize reflections. Short networks using the 115kbps versions need not be terminated, but, terminations are recommended unless power dissipation is an overriding concern.

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.

Built-In Driver Overload Protection

As stated previously, the RS-485 spec requires that drivers survive worst case bus contentions undamaged. These devices meet this requirement via driver output short circuit current limits, and on-chip thermal shutdown circuitry.

The driver output stages incorporate short circuit current limiting circuitry which ensures that the output current never exceeds the RS-485 spec, even at the common mode voltage range extremes.

In the event of a major short circuit condition, devices also include a thermal shutdown feature that disables the drivers whenever the die temperature becomes excessive. This eliminates the power dissipation, allowing the die to cool. The drivers automatically re-enable after the die temperature drops about 15 degrees. If the contention persists, the thermal shutdown/re-enable cycle repeats until the fault is cleared. Receivers stay operational during thermal shutdown.

Low Power Shutdown Mode

These CMOS transceivers all use a fraction of the power required by their bipolar counterparts, but they also include a shutdown feature that reduces the already low quiescent I_{CC} to a 70nA trickle. These devices enter shutdown whenever the receiver and driver are **simultaneously** disabled ($\overline{RE} = V_{CC}$ and $DE = GND$) for a period of at least 600ns. Disabling both the driver and the receiver for less than 60ns guarantees that the transceiver will not enter shutdown.

Note that receiver and driver enable times increase when the transceiver enables from shutdown. Refer to Notes 7, 8, 9, 10 and 11, at the end of the Electrical Specification table on page 8, for more information.

Typical Performance Curves $V_{CC} = 5V$, $T_A = +25^\circ C$; Unless Otherwise Specified

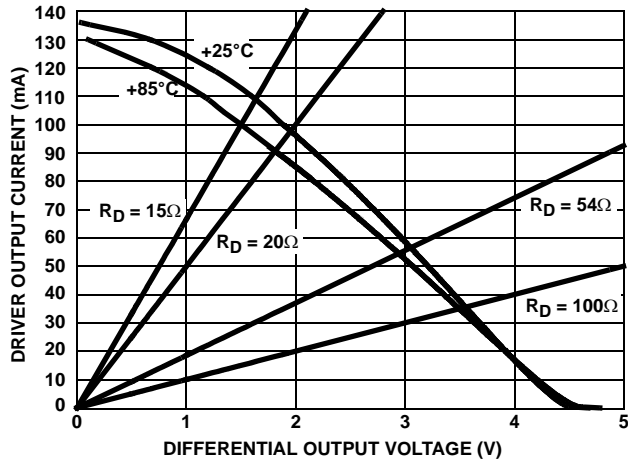


FIGURE 8. DRIVER OUTPUT CURRENT vs DIFFERENTIAL OUTPUT VOLTAGE

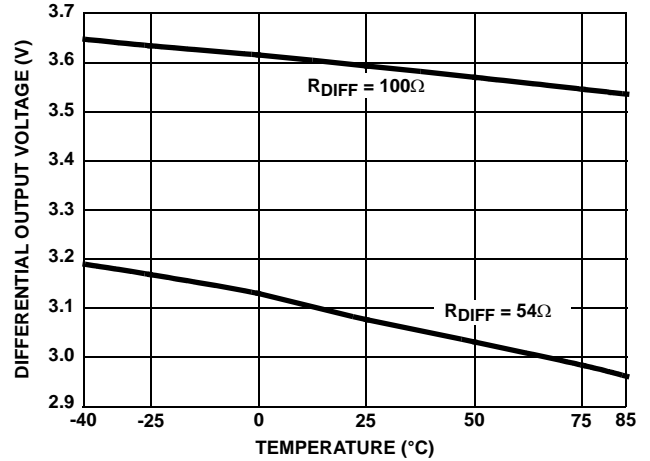


FIGURE 9. DRIVER DIFFERENTIAL OUTPUT VOLTAGE vs TEMPERATURE

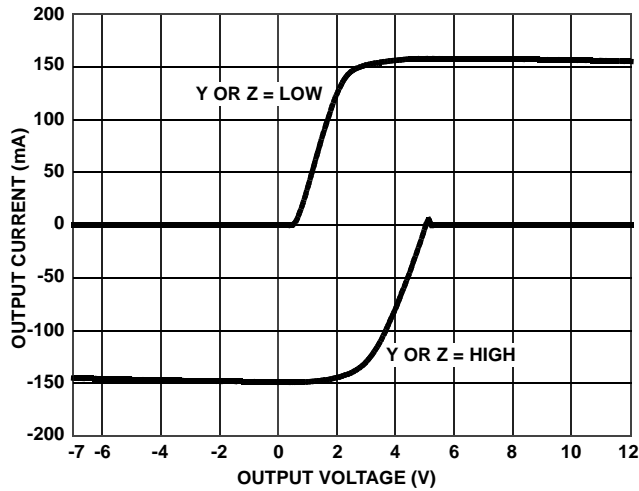


FIGURE 10. DRIVER OUTPUT CURRENT vs SHORT CIRCUIT VOLTAGE

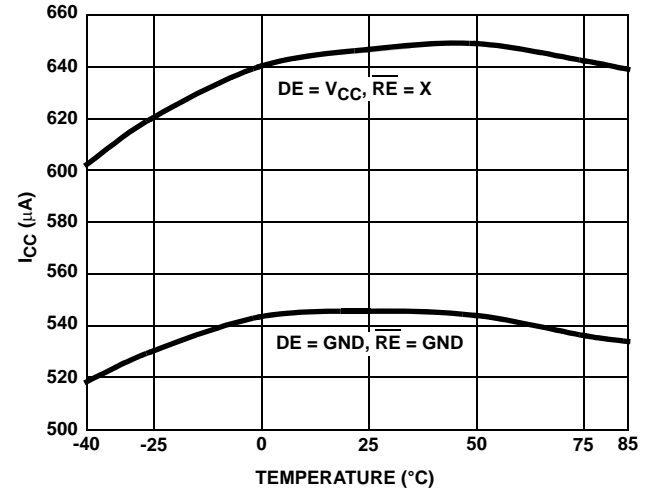


FIGURE 11. SUPPLY CURRENT vs TEMPERATURE

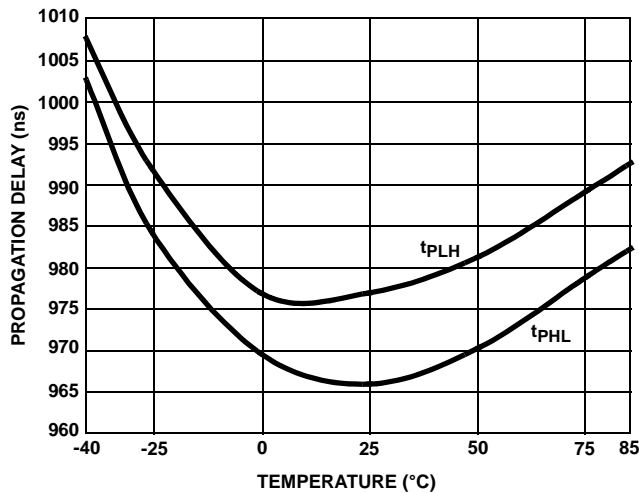


FIGURE 12. DRIVER DIFFERENTIAL PROPAGATION DELAY vs TEMPERATURE (ISL3150E, ISL3152E)

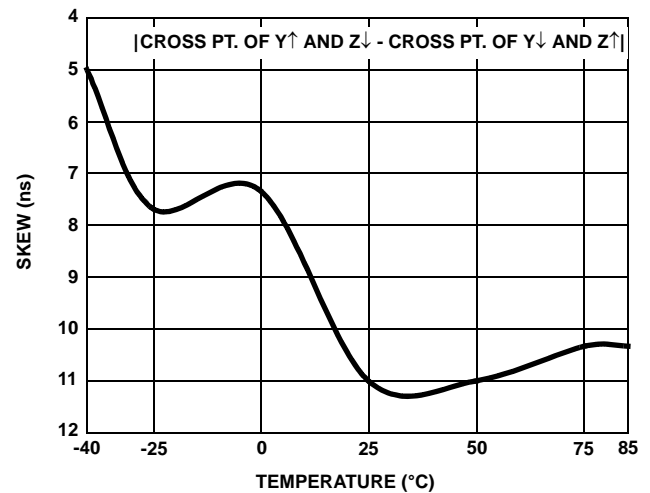


FIGURE 13. DRIVER DIFFERENTIAL SKEW vs TEMPERATURE (ISL3150E, ISL3152E)

Typical Performance Curves $V_{CC} = 5V, T_A = +25^\circ C$; Unless Otherwise Specified (Continued)

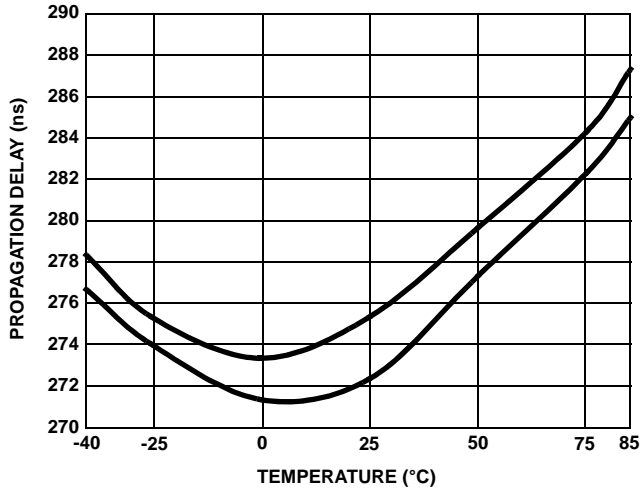


FIGURE 14. DRIVER DIFFERENTIAL PROPAGATION DELAY vs TEMPERATURE (ISL3153E, ISL3155E)

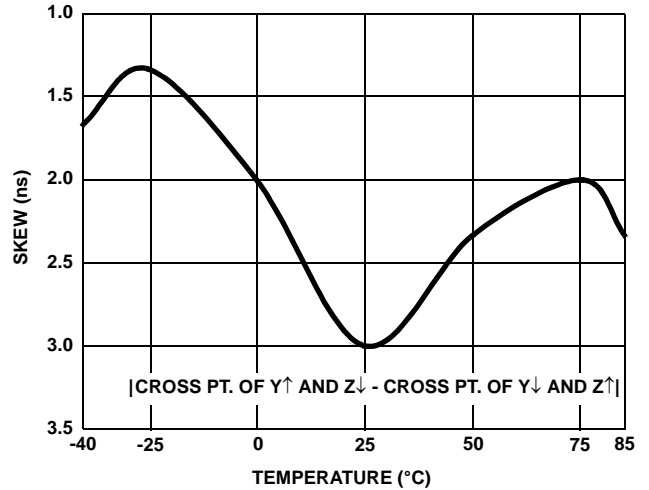


FIGURE 15. DRIVER DIFFERENTIAL SKEW vs TEMPERATURE (ISL3153E, ISL3155E)

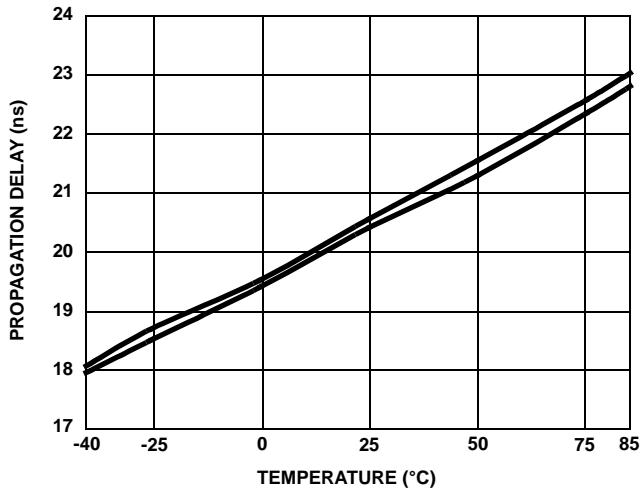


FIGURE 16. DRIVER DIFFERENTIAL PROPAGATION DELAY vs TEMPERATURE (ISL3156E, ISL3158E)

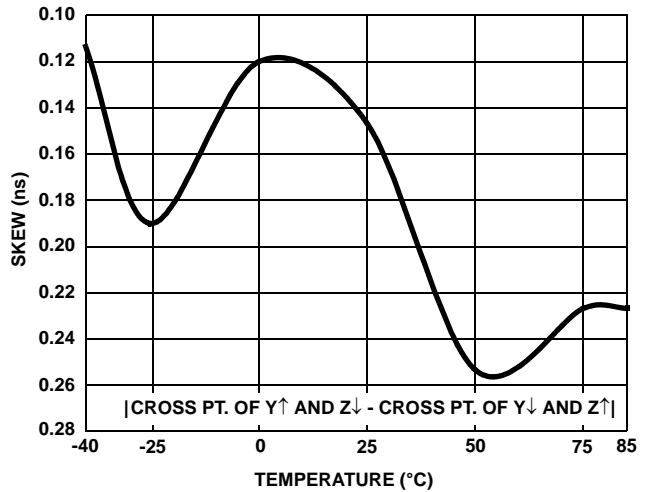


FIGURE 17. DRIVER DIFFERENTIAL SKEW vs TEMPERATURE (ISL3156E, ISL3158E)

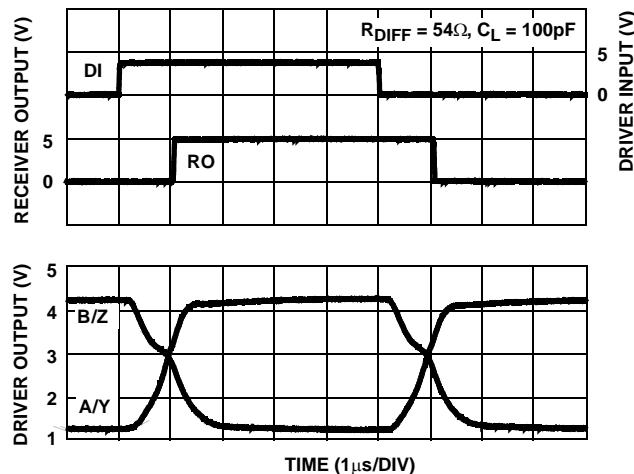


FIGURE 18. DRIVER AND RECEIVER WAVEFORMS, (ISL3150E, ISL3152E)

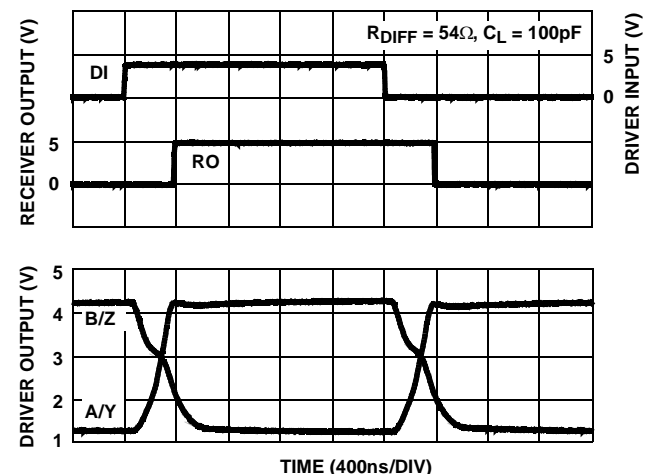


FIGURE 19. DRIVER AND RECEIVER WAVEFORMS, (ISL3153E, ISL3155E)

Typical Performance Curves $V_{CC} = 5V$, $T_A = +25^\circ C$; Unless Otherwise Specified (Continued)

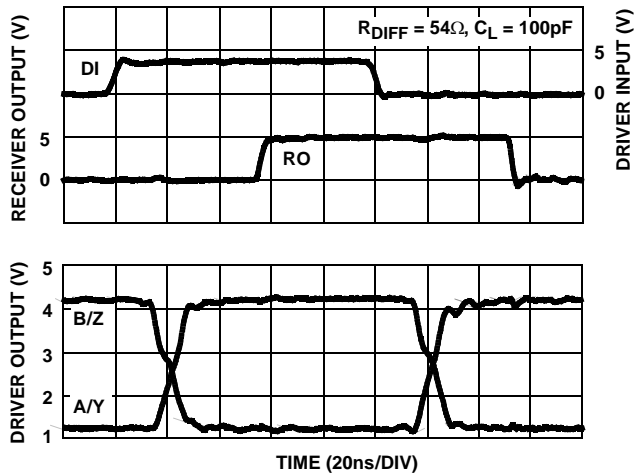


FIGURE 20. DRIVER AND RECEIVER WAVEFORMS, (ISL3156E, ISL3158E)

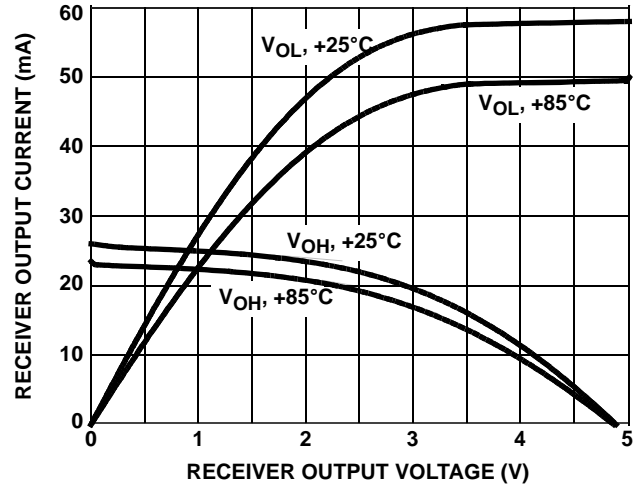


FIGURE 21. RECEIVER OUTPUT CURRENT vs RECEIVER OUTPUT VOLTAGE

Die Characteristics

SUBSTRATE POTENTIAL (POWERED UP):

GND

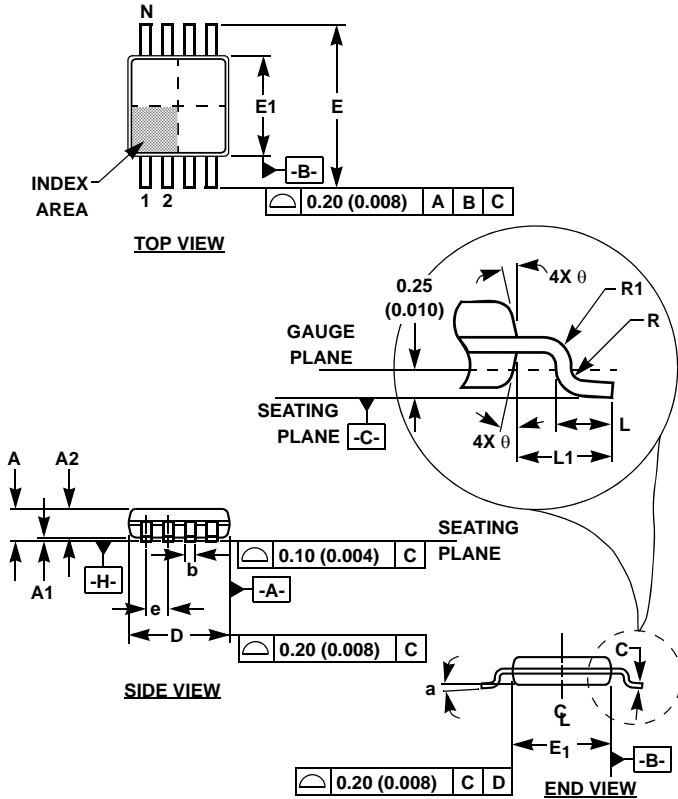
TRANSISTOR COUNT:

530

PROCESS:

Si Gate BiCMOS

Mini Small Outline Plastic Packages (MSOP)



M8.118 (JEDEC MO-187AA)
8 LEAD MINI SMALL OUTLINE PLASTIC PACKAGE

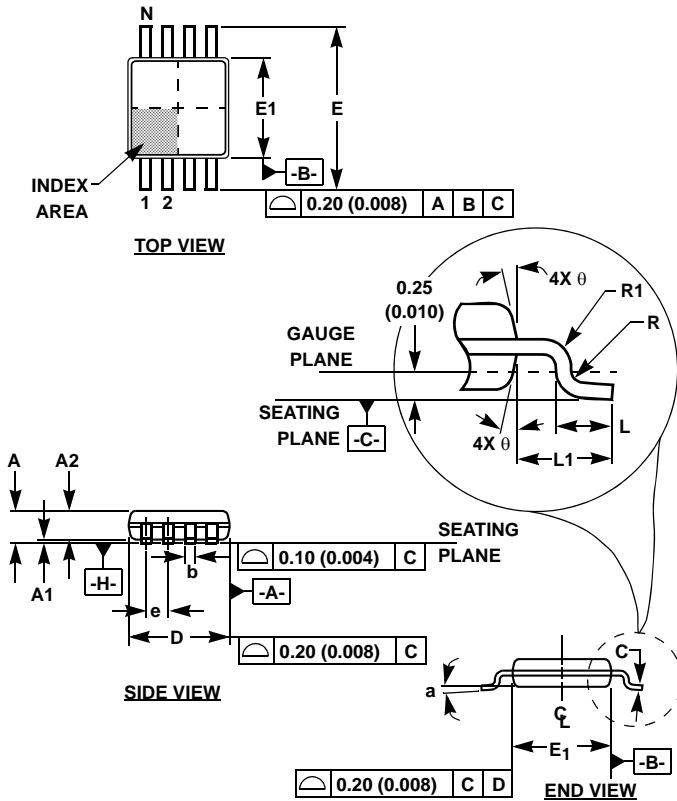
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.037	0.043	0.94	1.10	-
A1	0.002	0.006	0.05	0.15	-
A2	0.030	0.037	0.75	0.95	-
b	0.010	0.014	0.25	0.36	9
c	0.004	0.008	0.09	0.20	-
D	0.116	0.120	2.95	3.05	3
E1	0.116	0.120	2.95	3.05	4
e	0.026 BSC		0.65 BSC		-
E	0.187	0.199	4.75	5.05	-
L	0.016	0.028	0.40	0.70	6
L1	0.037 REF		0.95 REF		-
N	8		8		7
R	0.003	-	0.07	-	-
R1	0.003	-	0.07	-	-
θ	5°	15°	5°	15°	-
α	0°	6°	0°	6°	-

Rev. 2 01/03

NOTES:

1. These package dimensions are within allowable dimensions of JEDEC MO-187BA.
2. Dimensioning and tolerancing per ANSI Y14.5M-1994.
3. Dimension "D" does not include mold flash, protrusions or gate burrs and are measured at Datum Plane. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension "E1" does not include interlead flash or protrusions and are measured at Datum Plane. [-H-] Interlead flash and protrusions shall not exceed 0.15mm (0.006 inch) per side.
5. Formed leads shall be planar with respect to one another within 0.10mm (0.004) at seating Plane.
6. "L" is the length of terminal for soldering to a substrate.
7. "N" is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. Dimension "b" does not include dambar protrusion. Allowable dambar protrusion shall be 0.08mm (0.003 inch) total in excess of "b" dimension at maximum material condition. Minimum space between protrusion and adjacent lead is 0.07mm (0.0027 inch).
10. Datums [-A-] and [-B-] to be determined at Datum plane [-H-].
11. Controlling dimension: MILLIMETER. Converted inch dimensions are for reference only.

Mini Small Outline Plastic Packages (MSOP)



M10.118 (JEDEC MO-187BA)
10 LEAD MINI SMALL OUTLINE PLASTIC PACKAGE

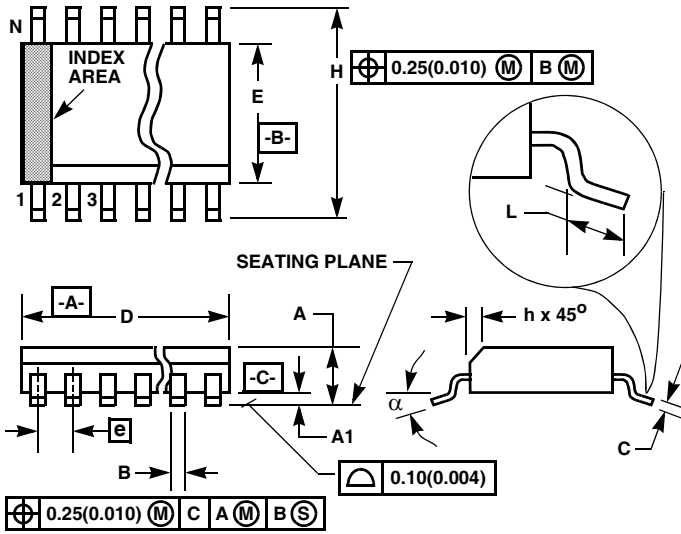
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.037	0.043	0.94	1.10	-
A1	0.002	0.006	0.05	0.15	-
A2	0.030	0.037	0.75	0.95	-
b	0.007	0.011	0.18	0.27	9
c	0.004	0.008	0.09	0.20	-
D	0.116	0.120	2.95	3.05	3
E1	0.116	0.120	2.95	3.05	4
e	0.020 BSC		0.50 BSC		-
E	0.187	0.199	4.75	5.05	-
L	0.016	0.028	0.40	0.70	6
L1	0.037 REF		0.95 REF		-
N	10		10		7
R	0.003	-	0.07	-	-
R1	0.003	-	0.07	-	-
θ	5°	15°	5°	15°	-
α	0°	6°	0°	6°	-

Rev. 0 12/02

NOTES:

1. These package dimensions are within allowable dimensions of JEDEC MO-187BA.
2. Dimensioning and tolerancing per ANSI Y14.5M-1994.
3. Dimension "D" does not include mold flash, protrusions or gate burrs and are measured at Datum Plane. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension "E1" does not include interlead flash or protrusions and are measured at Datum Plane. -H- Interlead flash and protrusions shall not exceed 0.15mm (0.006 inch) per side.
5. Formed leads shall be planar with respect to one another within 0.10mm (.004) at seating Plane.
6. "L" is the length of terminal for soldering to a substrate.
7. "N" is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. Dimension "b" does not include dambar protrusion. Allowable dambar protrusion shall be 0.08mm (0.003 inch) total in excess of "b" dimension at maximum material condition. Minimum space between protrusion and adjacent lead is 0.07mm (0.0027 inch).
10. Datums -A- and -B- to be determined at Datum plane -H-.
11. Controlling dimension: MILLIMETER. Converted inch dimensions are for reference only.

Small Outline Plastic Packages (SOIC)



M14.15 (JEDEC MS-012-AB ISSUE C)
14 LEAD NARROW BODY SMALL OUTLINE PLASTIC PACKAGE

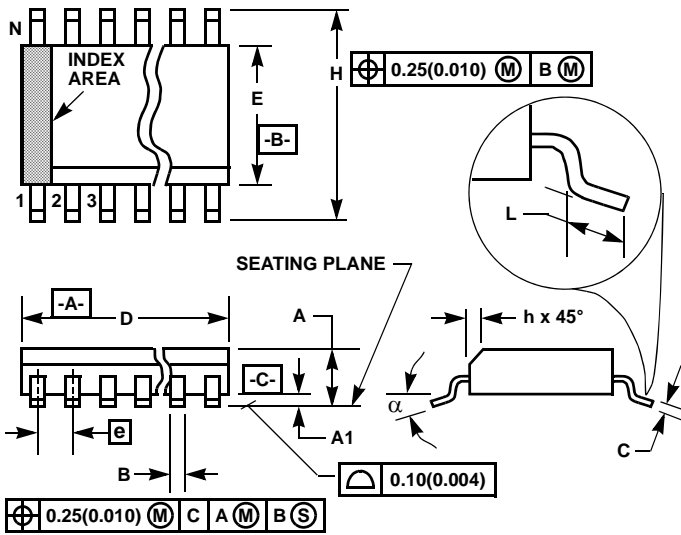
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.0532	0.0688	1.35	1.75	-
A1	0.0040	0.0098	0.10	0.25	-
B	0.013	0.020	0.33	0.51	9
C	0.0075	0.0098	0.19	0.25	-
D	0.3367	0.3444	8.55	8.75	3
E	0.1497	0.1574	3.80	4.00	4
e	0.050 BSC		1.27 BSC		-
H	0.2284	0.2440	5.80	6.20	-
h	0.0099	0.0196	0.25	0.50	5
L	0.016	0.050	0.40	1.27	6
N	14		14		7
alpha	0°	8°	0°	8°	-

NOTES:

1. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication Number 95.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension "E" does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
6. "L" is the length of terminal for soldering to a substrate.
7. "N" is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. The lead width "B", as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch).
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

Rev. 0 12/93

Small Outline Plastic Packages (SOIC)



M8.15 (JEDEC MS-012-AA ISSUE C)
8 LEAD NARROW BODY SMALL OUTLINE PLASTIC PACKAGE

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.0532	0.0688	1.35	1.75	-
A1	0.0040	0.0098	0.10	0.25	-
B	0.013	0.020	0.33	0.51	9
C	0.0075	0.0098	0.19	0.25	-
D	0.1890	0.1968	4.80	5.00	3
E	0.1497	0.1574	3.80	4.00	4
e	0.050 BSC		1.27 BSC		-
H	0.2284	0.2440	5.80	6.20	-
h	0.0099	0.0196	0.25	0.50	5
L	0.016	0.050	0.40	1.27	6
N	8		8		7
α	0°	8°	0°	8°	-

NOTES:

1. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication Number 95.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
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Rev. 1 6/05

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