ICL3224E, ICL3226E, ICL3244E

±15kV ESD Protected, +3V to +5.5V, 1µA, 250kbps, RS-232 Transceivers with Enhanced Automatic Powerdown

The ICL3224E, ICL3226E, and ICL3244E devices are 3.0V to 5.5V powered RS-232 transmitters/receivers that meet EIA/TIA-232 and V.28/V.24 specifications, even at V_{CC} = 3.0V. They provide ±15kV ESD protection (IEC61000-4-2 Air Gap and Human Body Model) on transmitter outputs and receiver inputs (RS-232 pins). Targeted applications are PDAs, Palmtops, and notebook and laptop computers where the low operational power and even lower standby power consumption are critical. Efficient on-chip charge pumps coupled with manual and enhanced automatic powerdown functions, reduce the standby supply current to a 1µA trickle. Small footprint packaging and the use of small, low value capacitors ensure board space savings. Data rates greater than 250kbps are ensured at worst case load conditions. This family is fully compatible with 3.3V only systems, mixed 3.3V and 5.0V systems, and 5.0V only systems.

The ICL3244E is a 3-driver, 5-receiver device that provides a complete serial port suitable for laptop or notebook computers. It also includes a noninverting always-active receiver for “wake-up” capability.

The ICL3224E, ICL3226E, and ICL3244E feature an enhanced automatic powerdown function that powers down the on-chip power supply and driver circuits. Powerdown occurs when all receiver and transmitter inputs detect no signal transitions for a period of 30s. These devices power back up automatically whenever they sense a transition on any transmitter or receiver input.

Table 1 summarizes the features of the device represented by this datasheet and AN9863 summarizes the features of each device comprising the ICL32xxE 3V family.

Related Literature

For a full list of related documents, visit our website:

• ICL3224E, ICL3226E, and ICL3244E device pages

Features

- Pb-Free Plus Anneal Available (RoHS Compliant)
- ESD protection for RS-232 I/O pins to ±15kV (IEC61000)
- Manual and enhanced automatic powerdown
- Drop in replacements for MAX3224E, MAX3226E, MAX3244E
- Meets EIA/TIA-232 and V.28/V.24 specifications at 3V
- RS-232 compatible with V_{CC} = 2.7V
- Latch-up free
- On-chip voltage converters require only four external 0.1µF capacitors
- Ensured mouse driveability (ICL3244E)
- “Ready to Transmit” indicator output (ICL3224E/ICL3226E)
- Receiver hysteresis for improved noise immunity
- Ensured minimum data rate 250kbps
- Ensured minimum slew rate 6V/µs
- Wide power supply range single +3V to +5.5V
- Low supply current in powerdown state 1µA

Applications

- Any system requiring RS-232 communication ports
  - Battery powered, hand-held, and portable equipment
  - Laptop computers, notebooks, palmtops
  - Modems, printers, and other peripherals
  - Digital cameras
  - Cellular/mobile phones

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1. Overview

1.1 Typical Operating Circuits

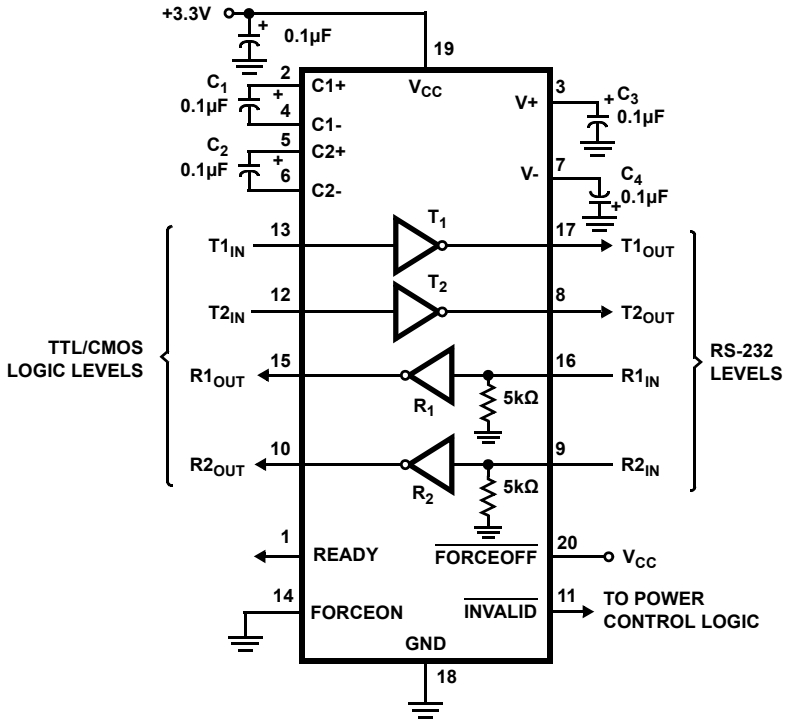


Figure 1. ICL3224E

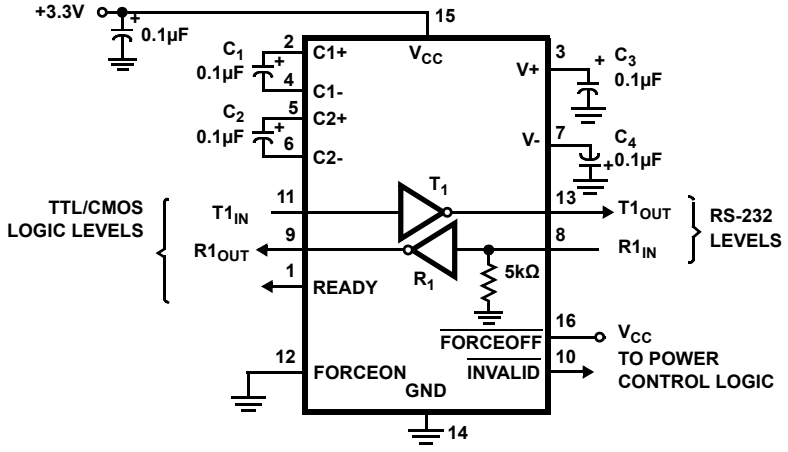


Figure 2. ICL3226E

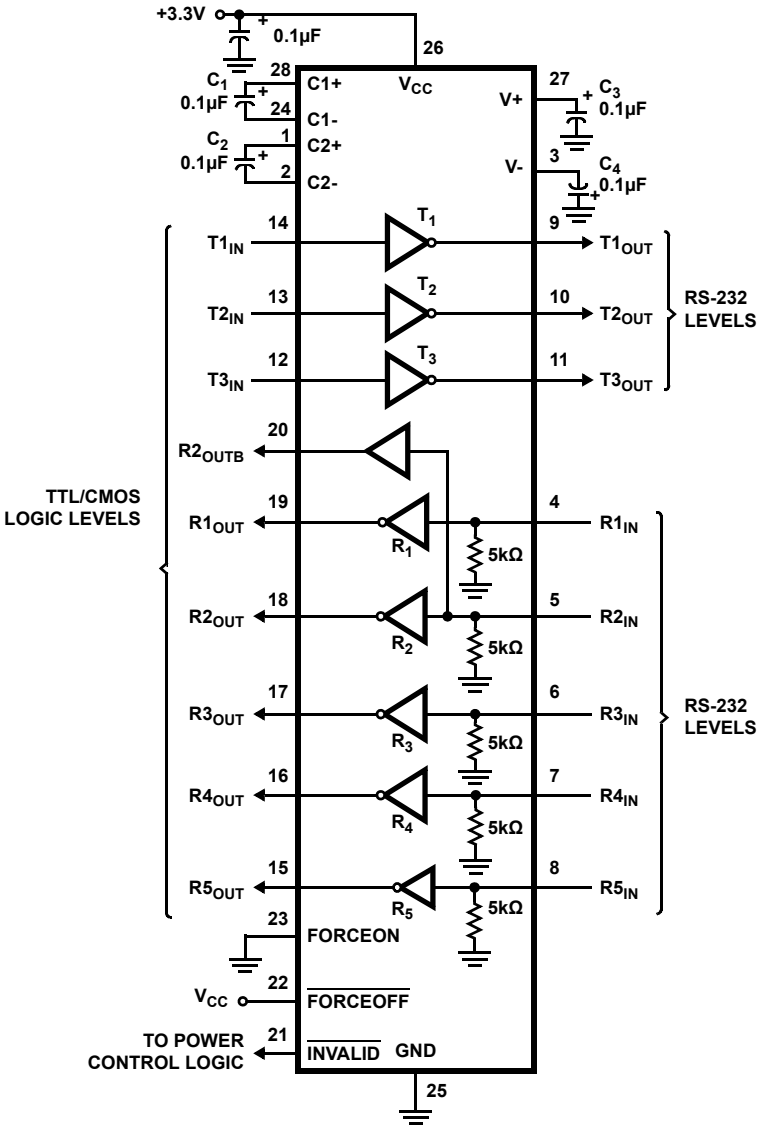


Figure 3. ICL3244E

1.2 Ordering Information

Part Number (Notes 2, 3)	Part Marking	Temp Range (°C)	Tape and Reel (Units) (Note 1)	Package (RoHS Compliant)	Pkg. Dwg. #
ICL3224EIAZ	3224EIAZ	-40 to 85		20 Ld SSOP	M20.209
ICL3224EIAZ-T	3224EIAZ	-40 to 85	1k	20 Ld SSOP	M20.209
ICL3224ECAZ **(No longer available, recommended replacement: ICL3224EIAZ)**	3224ECAZ	0 to 70		20 Ld SSOP	M20.209
ICL3224ECAZ-T **(No longer available, recommended replacement: ICL3224EIAZ-T)**	3224ECAZ	0 to 70	1k	20 Ld SSOP	M20.209
ICL3226EIAZ	3226EIAZ	-40 to 85		16 Ld SSOP	M16.209
ICL3226EIAZ-T	3226EIAZ	-40 to 85	1k	16 Ld SSOP	M16.209
ICL3226ECAZ **(No longer available, recommended replacement: ICL3226EIAZ)**	3226ECAZ	0 to 70		16 Ld SSOP	M16.209
ICL3226ECAZ-T **(No longer available, recommended replacement: ICL3226EIAZ-T)**	3226ECAZ	0 to 70	1k	16 Ld SSOP	M16.209
ICL3244EIAZ	ICL3244EIAZ	-40 to 85		28 Ld SSOP	M28.209
ICL3244EIAZ-T	ICL3244EIAZ	-40 to 85	1k	28 Ld SSOP	M28.209
ICL3244ECAZ **(No longer available, recommended replacement: ICL3244EIAZ)**	ICL3244ECAZ	0 to 70		28 Ld SSOP	M28.209
ICL3244ECAZ-T **(No longer available, recommended replacement: ICL3244EIAZ-T)**	ICL3244ECAZ	0 to 70	1k	28 Ld SSOP	M28.209

Notes:

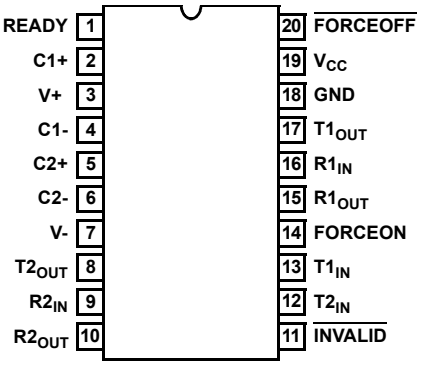
1. See TB347 for details about reel specifications.
2. These Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). 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.
3. For Moisture Sensitivity Level (MSL), see the ICL3224E, ICL3226E, and ICL3244E device pages. For more information about MSL, see TB363.

Table 1. Summary of Features

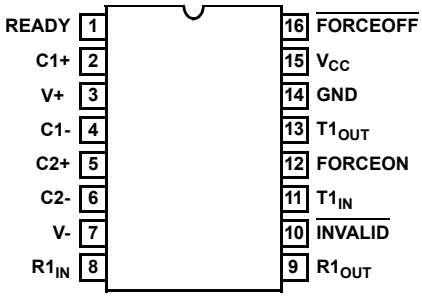
Part Number	Number of Tx.	Number of Rx.	Number of Monitor Rx. (R_{OUTB})	Data Rate (kbps)	Rx. Enable Function?	Ready Output?	Manual Powerdown?	Enhanced Automatic Powerdown Function?
ICL3224E	2	2	0	250	No	Yes	Yes	Yes
ICL3226E	1	1	0	250	No	Yes	Yes	Yes
ICL3244E	3	5	1	250	No	No	Yes	Yes

1.3 Pin Configurations

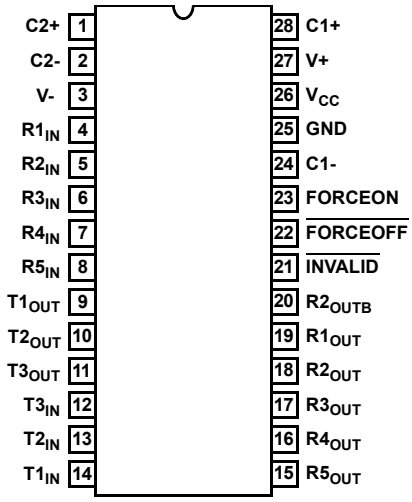
ICL3224E (SSOP)
Top View



ICL3226E (SSOP)
Top View



ICL3244E (SSOP)
Top View



1.4 Pin Descriptions

Pin	Function
V_{CC}	System power supply input (3.0V to 5.5V).
V+	Internally generated positive transmitter supply (+5.5V).
V-	Internally generated negative transmitter supply (-5.5V).
GND	Ground connection.
C1+	External capacitor (voltage doubler) is connected to this lead.
C1-	External capacitor (voltage doubler) is connected to this lead.
C2+	External capacitor (voltage inverter) is connected to this lead.
C2-	External capacitor (voltage inverter) is connected to this lead.
T_{IN}	TTL/CMOS compatible transmitter Inputs.

Pin	Function
T_{OUT}	±15kV ESD Protected, RS-232 level (nominally ±5.5V) transmitter outputs.
R_{IN}	±15kV ESD Protected, RS-232 compatible receiver inputs.
R_{OUT}	TTL/CMOS level receiver outputs.
R_{OUTB}	TTL/CMOS level, noninverting, always enabled receiver outputs.
$\overline{\text{INVALID}}$	Active low output that indicates if no valid RS-232 levels are present on any receiver input.
READY	Active high output that indicates when the ICL32XXE is ready to transmit (V- ≤ -4V)
$\overline{\text{FORCEOFF}}$	Active low to shut down transmitters and on-chip power supply, which overrides any automatic circuitry and FORCEON (See Table 2).
FORCEON	Active high input to override automatic powerdown circuitry and keeps transmitters active. ($\overline{\text{FORCEOFF}}$ must be high).

2. Specifications

2.1 Absolute Maximum Ratings

Parameter	Minimum	Maximum	Unit
V_{CC} to GND	-0.3	6	V
V+ to GND	-0.3	7	V
V- to GND	+0.3	-7	V
V+ to V-		14	V
Input Voltages			
T_{IN}, $\overline{FORCEOFF}$, FORCEON	-0.3	6	V
R_{IN}		±25	V
Output Voltages			
T_{OUT}		±13.2	V
R_{OUT}, $\overline{INVALID}$, READY	-0.3	V_{CC} + 0.3	V
Short-Circuit Duration			
T_{OUT}	Continuous		
ESD Rating	(See "ESD Performance" on page 10)		

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

2.2 Thermal Information

Thermal Resistance (Typical, Note 4)	θ_{JA} (°C/W)
16 Ld SSOP Package	140
20 Ld SSOP Package	125
28 Ld SSOP Package	100

Notes:
4. θ_{JA} is measured with the component mounted on a low-effective thermal conductivity test board in free air. See TB379 for details.

Parameter	Minimum	Maximum	Unit
Maximum Junction Temperature (Plastic Package)		+150	°C
Maximum Storage Temperature Range	-65	+150	°C
Pb-Free Reflow Profile	see TB493		

2.3 Recommended Operating Conditions

Parameter	Minimum	Maximum	Unit
Temperature Range			
ICL32xxEC	0	+70	°C
ICL32xxEI	-40	+85	°C

2.4 Electrical Specifications

Test conditions: V_{CC} = 3V to 5.5V, C_1 - C_4 = 0.1µF; unless otherwise specified. Typicals are at T_A = +25°C.

Parameter	Test Conditions		Temp (°C)	Min	Typ	Max	Unit
DC Characteristics							
Supply Current, Automatic Powerdown	All R_{IN} Open, FORCEON = GND, $\overline{FORCEOFF}$ = V_{CC}		+25	-	1.0	10	µA
Supply Current, Powerdown	$\overline{FORCEOFF}$ = GND		+25	-	1.0	10	µA
Supply Current, Automatic Powerdown Disabled	All outputs unloaded, FORCEON = $\overline{FORCEOFF}$ = V_{CC}		+25	-	0.3	1.0	mA
Logic and Transmitter Inputs and Receiver Outputs							
Input Logic Threshold Low	T_{IN}, FORCEON, $\overline{FORCEOFF}$		Full	-	-	0.8	V
Input Logic Threshold High	T_{IN}, FORCEON, $\overline{FORCEOFF}$	V_{CC} = 3.3V	Full	2.0	-	-	V
		V_{CC} = 5.0V	Full	2.4	-	-	V
Transmitter Input Hysteresis			+25	-	0.5	-	V
Input Leakage Current	T_{IN}, FORCEON, $\overline{FORCEOFF}$		Full	-	±0.01	±1.0	µA
Output Leakage Current	$\overline{FORCEOFF}$ = GND, ICL3244E Only		Full	-	±0.05	±10	µA
Output Voltage Low	I_{OUT} = 1.6mA		Full	-	-	0.4	V
Output Voltage High	I_{OUT} = -1.0mA		Full	V_{CC} - 0.6	V_{CC} - 0.1	-	V
Receiver Inputs							
Input Voltage Range			Full	-25	-	25	V
Input Threshold Low	V_{CC} = 3.3V		+25	0.6	1.2	-	V
	V_{CC} = 5.0V		+25	0.8	1.5	-	V
Input Threshold High	V_{CC} = 3.3V		+25	-	1.5	2.4	V
	V_{CC} = 5.0V		+25	-	1.8	2.4	V
Input Hysteresis			+25	-	0.5	-	V
Input Resistance			+25	3	5	7	kΩ
Transmitter Outputs							
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to Ground		Full	±5.0	±5.4	-	V
Output Resistance	V_{CC} = V+ = V- = 0V, transmitter output = ±2V		Full	300	10M	-	W
Output Short-Circuit Current			Full	-	±35	±60	mA
Output Leakage Current	V_{OUT} = ±12V, V_{CC} = 0V or 3V to 5.5V Automatic Powerdown or $\overline{FORCEOFF}$ = GND		Full	-	-	±25	µA
Mouse Driveability (ICL3244E only)							
Transmitter Output Voltage (See Figure 20 on page 20)	$T1_{IN}$ = $T2_{IN}$ = GND, $T3_{IN}$ = V_{CC}, $T3_{OUT}$ loaded with 3kΩ to GND, $T1_{OUT}$ and $T2_{OUT}$ loaded with 2.5mA each		Full	±5	-	-	V
Enhanced Automatic Powerdown (FORCEON = GND, $\overline{FORCEOFF}$ = V_{CC})							
Receiver Input Thresholds to $\overline{INVALID}$ High	See Figure 15 on page 17		Full	-2.7	-	2.7	V
Receiver Input Thresholds to $\overline{INVALID}$ Low	See Figure 15 on page 17		Full	-0.3	-	0.3	V
$\overline{INVALID}$, READY Output Voltage Low	I_{OUT} = 1.6mA		Full	-	-	0.4	V
$\overline{INVALID}$, READY Output Voltage High	I_{OUT} = -1.0mA		Full	V_{CC} - 0.6	-	-	V

Test conditions: V_{CC} = 3V to 5.5V, C_1 - C_4 = 0.1µF; unless otherwise specified. Typicals are at T_A = +25°C. **(Continued)**

Parameter	Test Conditions		Temp (°C)	Min	Typ	Max	Unit
Receiver Positive or Negative Threshold to INVALID High Delay (t_{INVH})			+25	-	1	-	µs
Receiver Positive or Negative Threshold to INVALID Low Delay (t_{INVL})			+25	-	30	-	µs
Receiver or Transmitter Edge to Transmitters Enabled Delay (t_{WU})	(Note 5)		+25	-	100	-	µs
Receiver or Transmitter Edge to Transmitters Disabled Delay ($t_{AUTOPWDN}$)	(Note 5)		Full	15	30	60	sec
Timing Characteristics							
Maximum Data Rate	R_L = 3kΩ, C_L = 1000pF, one transmitter switching		Full	250	500	-	kbps
Receiver Propagation Delay	Receiver input to receiver output, C_L = 150pF	t_{PHL}	+25	-	0.15	-	µs
		t_{PLH}	+25	-	0.15	-	µs
Receiver Output Enable Time	Normal operation (ICL3244E only)		+25	-	200	-	ns
Receiver Output Disable Time	Normal operation (ICL3244E only)		+25	-	200	-	ns
Transmitter Skew	t_{PHL} - t_{PLH}		+25	-	100	-	ns
Receiver Skew	t_{PHL} - t_{PLH}		+25	-	50	-	ns
Transition Region Slew Rate	V_{CC} = 3.3V, R_L = 3kΩ to 7kΩ, measured from 3V to -3V or -3V to 3V	C_L = 150pF to 1000pF	+25	6	-	30	V/µs
		C_L = 150pF to 2500pF	+25	4	8	30	V/µs
ESD Performance							
RS-232 Pins (T_{OUT}, R_{IN})	Human Body Model		+25	-	±15	-	kV
	IEC61000-4-2 Contact Discharge		+25	-	±8	-	kV
	IEC61000-4-2 Air Gap Discharge		+25	-	±15	-	kV
All Other Pins	Human body model (HBM)		+25	-	±3	-	kV

Notes:

5. An “edge” is defined as a transition through the transmitter or receiver input thresholds.

3. Typical Performance Curves

Typical Performance Curves V_{CC} = 3.3V, T_A = 25°C

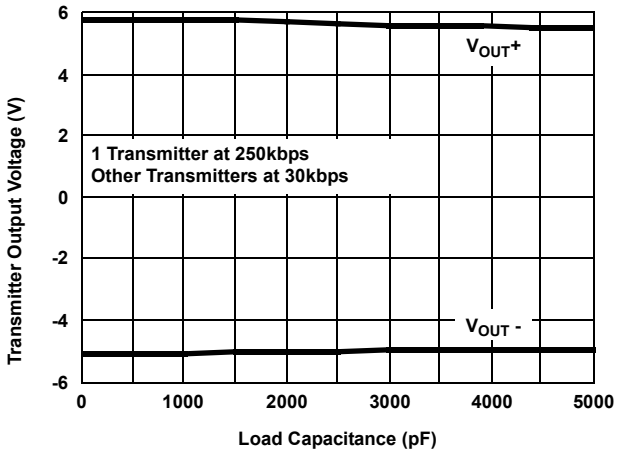


Figure 4. Transmitter Output Voltage vs Load Capacitance

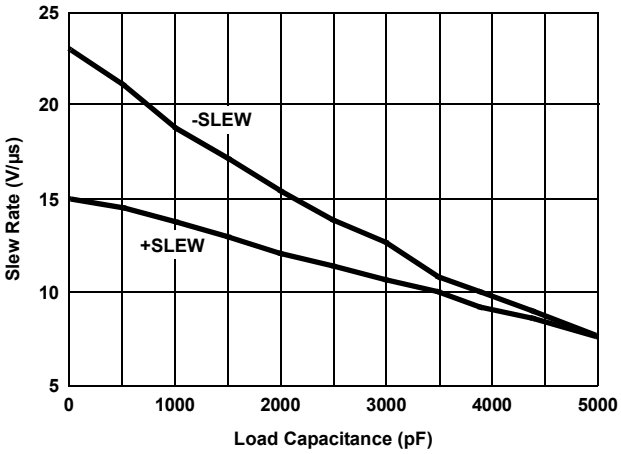


Figure 5. Slew Rate vs Load Capacitance

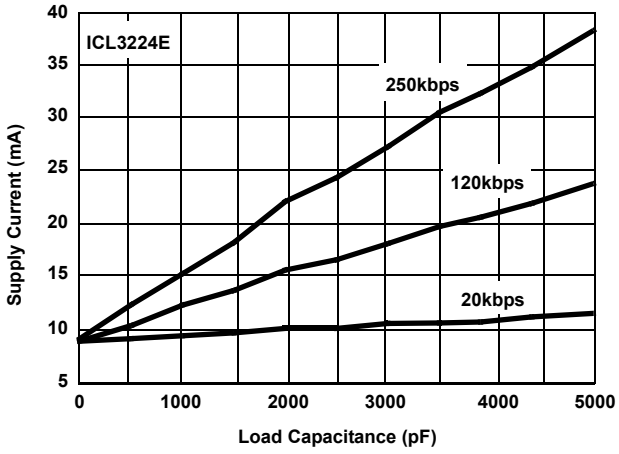


Figure 6. Supply Current vs Load Capacitance when Transmitting Data

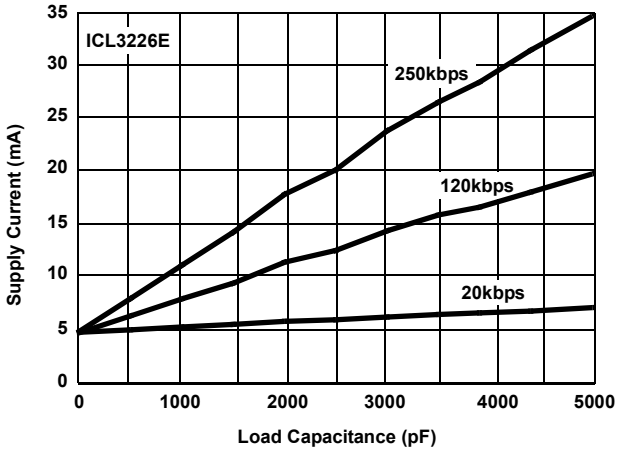


Figure 7. Supply Current vs Load Capacitance When Transmitting Data

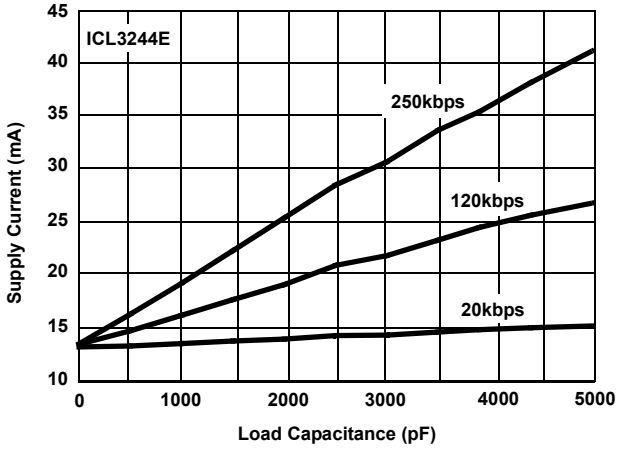


Figure 8. Supply Current vs Load Capacitance When Transmitting Data

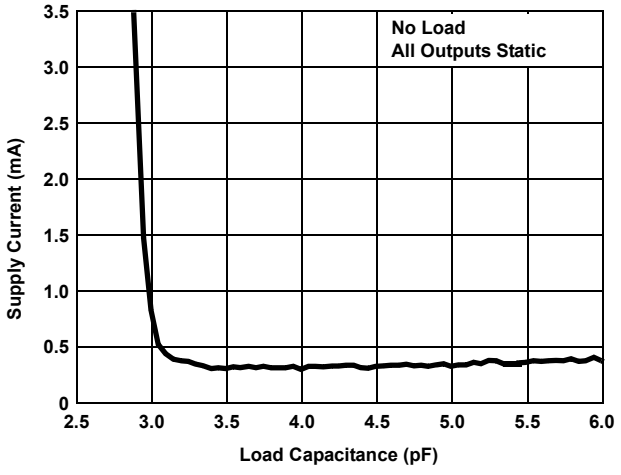


Figure 9. Supply Current vs Supply Voltage

4. Application Information

The ICL3224E, ICL3226E, and ICL3244E operate from a single +3V to +5.5V supply, ensure a 250kbps minimum data rate, require only four small external 0.1µF capacitors, feature low power consumption, and meet all EIA RS-232C and V.28 specifications.

4.1 Charge-Pump

The ICL32xxE use regulated on-chip dual charge pumps as voltage doublers, and voltage inverters to generate ±5.5V transmitter supplies from a V_{CC} supply as low as 3.0V, which allows these devices to maintain RS-232 compliant output levels over the ±10% tolerance range of 3.3V powered systems. The efficient on-chip power supplies require only four small, external 0.1µF capacitors for the voltage doubler and inverter functions at V_{CC} = 3.3V. See the Capacitor Selection section, and Table 6 on page 19 for capacitor recommendations for other operating conditions. The charge pumps operate discontinuously turning off with the V+ and V- supplies are pumped up to the nominal values), resulting in significant power savings.

4.1.1 Charge Pump Abs Max Ratings

These 3V to 5V RS-232 transceivers have been fully characterized for 3.0V to 3.6V operation, and at critical points for 4.5V to 5.5V operation. Furthermore, load conditions were favorable using static logic states only.

The specified maximum values for V+ and V- are +7V and -7V respectively. These limits apply for V_{CC} values set to 3.0V and 3.6V (see Table 2). For V_{CC} values set to 4.5V and 5.5V, the maximum values for V+ and V- can approach +9V and -7V respectively (see Table 3). The breakdown characteristics for V+ and V- were measured with ±13V.

Table 2. V+ and V- Values for V_{CC} = 3.0V to 3.6V

C_1 (µF)	C_2, C_3, C_4 (µF)	Load	T1IN (Logic State)	V+ (V)		V- (V)	
				V_{CC} = 3.0V	V_{CC} = 3.6V	V_{CC} = 3.0V	V_{CC} = 3.6V
0.1	0.1	Open	H	5.8	6.56	-5.6	-5.88
			L	5.8	6.56	-5.6	-5.88
			2.4kbps	5.8	6.56	-5.6	-5.88
		3kΩ // 1000pF	H	5.88	6.6	-5.56	-5.92
			L	5.76	6.36	-5.56	-5.76
			2.4kbps	6	6.64	-5.64	-5.96
0.047	0.33	Open	H	5.68	6	-5.6	-5.6
			L	5.68	6	-5.6	-5.6
			2.4kbps	5.68	6	-5.6	-5.6
		3kΩ // 1000pF	H	5.76	6.08	-5.64	-5.64
			L	5.68	6.04	-5.6	-5.6
			2.4kbps	5.84	6.16	-5.64	-5.72
1	1	Open	H	5.88	6.24	-5.6	-5.6
			L	5.88	6.28	-5.6	-5.64
			2.4kbps	5.8	6.2	-5.6	-5.6
		3kΩ // 1000pF	H	5.88	6.44	-5.64	-5.72
			L	5.88	6.04	-5.64	-5.64
			2.4kbps	5.92	6.4	-5.64	-5.64

Table 3. V+ and V- Values for Vcc = 4.5V to 5.5V

C_1 (µF)	C_2, C_3, C_4 (µF)	Load	T1IN (Logic State)	V+ (V)		V- (V)	
				V_{CC} = 4.5V	V_{CC} = 5.5V	V_{CC} = 4.5V	V_{CC} = 5.5V
0.1	0.1	Open	H	7.44	8.48	-6.16	-6.4
			L	7.44	8.48	-6.16	-6.44
			2.4kbps	7.44	8.48	-6.17	-6.44
		3kΩ // 1000pF	H	7.76	8.88	-6.36	-6.72
			L	7.08	8	-5.76	-5.76
			2.4kbps	7.76	8.84	-6.4	-6.64
0.047	0.33	Open	H	6.44	6.88	-5.8	-5.88
			L	6.48	6.88	-5.84	-5.88
			2.4kbps	6.44	6.88	-5.8	-5.88
		3kΩ // 1000pF	H	6.64	7.28	-5.92	-6.04
			L	6.24	6.6	-5.52	-5.52
			2.4kbps	6.72	7.16	-5.92	-5.96
1	1	Open	H	6.84	7.6	-5.76	-5.76
			L	6.88	7.6	-5.76	-5.76
			2.4kbps	6.92	7.56	-5.72	-5.76
		3kΩ // 1000pF	H	7.28	8.16	-5.8	-5.92
			L	6.44	6.84	-5.64	-6.84
			2.4kbps	7.08	7.76	-5.8	-5.8

The resulting new maximum voltages at V+ and V- are listed in Table 4.

Table 4. New Measured Withstanding Voltages

V+, V- to Ground	±13V
V+ to V-	20V

4.2 Transmitters

The transmitters are proprietary, low dropout, inverting drivers that translate TTL/CMOS inputs to EIA/TIA-232 output levels. The transmitters are coupled with the on-chip ±5.5V supplies to deliver true RS-232 levels over a wide range of single supply system voltages.

Transmitter outputs disable and assume a high impedance state when the device enters the powerdown mode (see Table 5 on page 15). These outputs may be driven to ±12V when disabled.

All devices ensure a 250kbps data rate for full load conditions (3kΩ and 1000pF), $V_{CC} \geq 3.0V$, with one transmitter operating at full speed. Under more typical conditions of $V_{CC} \geq 3.3V$, R_L = 3kΩ, and C_L = 250pF, one transmitter easily operates at 1Mbps.

Transmitter inputs float if they are not connected and can cause I_{CC} to increase. Connect unused inputs to GND for the best performance.

4.3 Receivers

All the ICL32xxE devices contain standard inverting receivers, but only the ICL3244E receivers can tri-state using the $\overline{\text{FORCEOFF}}$ control line. The ICL3244E includes a noninverting (monitor) receiver (denoted by the R_{OUTB} label) that is always active regardless of the state of any control lines. Both receiver types convert RS-232 signals to CMOS output levels and accept inputs up to ±25V while presenting the required 3kΩ to 7kΩ input impedance

(see Figure 10) even if the power is off (V_{CC} = 0V). The receivers' Schmitt trigger input stage uses hysteresis to increase noise immunity and decrease errors due to slow input signal transitions.

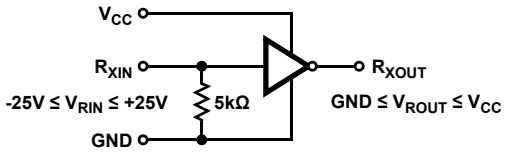


Figure 10. Inverting Receiver Connections

The ICL3244E inverting receivers disable during forced (manual) powerdown, but not during automatic powerdown (see Table 5 on page 15). Conversely, the monitor receiver remains active even during manual powerdown, which makes it extremely useful for Ring Indicator monitoring. Standard receivers driving powered down peripherals must be disabled to prevent current flow through the peripheral's protection diodes (see Figures 11 and 12). When powered down, they cannot be used for wake-up functions, but the corresponding monitor receiver can be dedicated to this task as shown in Figure 12.

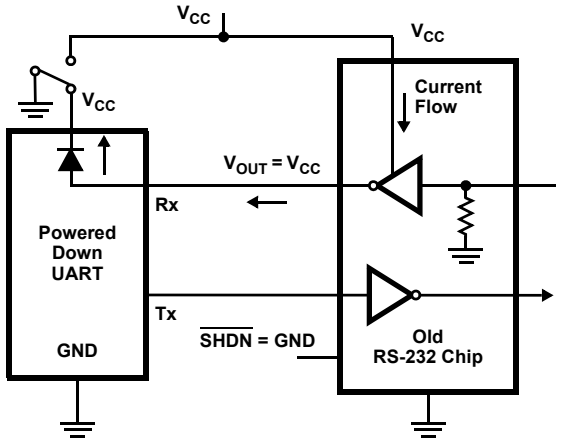


Figure 11. Power Drain Through Powered Down Peripheral

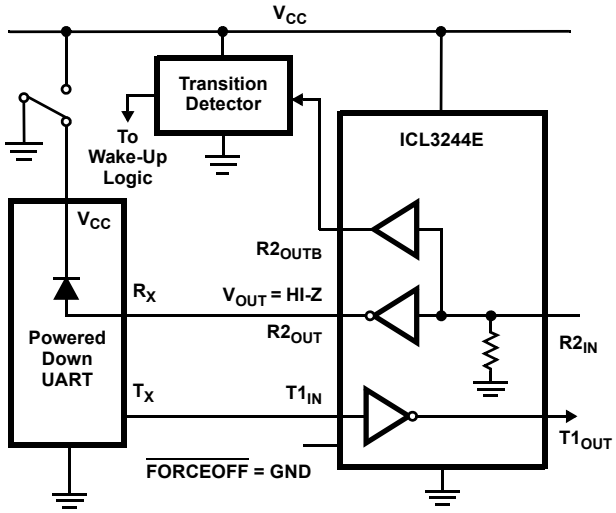


Figure 12. Disabled Receivers Prevent Power Drain

4.4 Powerdown Functionality

This 3V ISL32xxE devices require a nominal supply current of 0.3mA during normal operation (not in powerdown mode). This current is considerably less than the 5mA to 11mA current required of 5V RS-232 devices. The already low current requirement drops significantly when the device enters powerdown mode. In powerdown, supply current drops to 1µA, because the on-chip charge pump turns off (V+ collapses to V_{CC}, V- collapses to GND), and the transmitter outputs tri-state. Inverting receiver outputs may or may not disable in powerdown; see Table 5 for details. This micro-power mode makes these devices ideal for battery powered and portable applications.

Table 5. Powerdown Logic Truth Table

RCVR or XMTR EDGE Within 30 Sec?	$\overline{\text{FORCEOFF}}$ Input	FORCEON Input	Transmitter Outputs	Receiver Outputs	R_{OUTB} Outputs (Note 6)	RS-232 Level Present at Receiver Input?	$\overline{\text{INVALID}}$ Output	Mode of Operation
ICL3224E, ICL3226E								
No	H	H	Active	Active	N.A.	No	L	Normal Operation (Enhanced Auto Powerdown Disabled)
No	H	H	Active	Active	N.A.	Yes	H	
Yes	H	L	Active	Active	N.A.	No	L	Normal Operation (Enhanced Auto Powerdown Enabled)
Yes	H	L	Active	Active	N.A.	Yes	H	
No	H	L	High-Z	Active	N.A.	No	L	Powerdown Due to Enhanced Auto Powerdown Logic
No	H	L	High-Z	Active	N.A.	Yes	H	
X	L	X	High-Z	Active	N.A.	No	L	Manual Powerdown
X	L	X	High-Z	Active	N.A.	Yes	H	
ICL322XE - $\overline{\text{INVALID}}$ Driving FORCEON and $\overline{\text{FORCEOFF}}$ (Emulates Automatic Powerdown)								
X	Note 7	Note 7	Active	Active	N.A.	Yes	H	Normal Operation
X	Note 7	Note 7	High-Z	Active	N.A.	No	L	Forced Auto Powerdown
ICL3244E								
No	H	H	Active	Active	Active	No	L	Normal Operation (Enhanced Auto Powerdown Disabled)
No	H	H	Active	Active	Active	Yes	H	
Yes	H	L	Active	Active	Active	No	L	Normal Operation (Enhanced Auto Powerdown Enabled)
Yes	H	L	Active	Active	Active	Yes	H	
No	H	L	High-Z	Active	Active	No	L	Powerdown Due to Enhanced Auto Powerdown Logic
No	H	L	High-Z	Active	Active	Yes	H	
X	L	X	High-Z	High-Z	Active	No	L	Manual Powerdown
X	L	X	High-Z	High-Z	Active	Yes	H	
ICL3244E - $\overline{\text{INVALID}}$ Driving FORCEON and $\overline{\text{FORCEOFF}}$ (Emulates Automatic Powerdown)								
X	Note 7	Note 7	Active	Active	Active	Yes	H	Normal Operation
X	Note 7	Note 7	High-Z	High-Z	Active	No	L	Forced Auto Powerdown

Notes:

6. Applies only to the ICL3244E.
7. Input is connected to $\overline{\text{INVALID}}$ Output.

4.4.1 Software Controlled (Manual) Powerdown

The ISL32xxE devices allow you to force the IC into the low power, standby state, and use a two pin approach where the FORCEON and $\overline{\text{FORCEOFF}}$ inputs determine the IC's mode. For always enabled operation, FORCEON and $\overline{\text{FORCEOFF}}$ are both strapped high. Under logic or software control, only the $\overline{\text{FORCEOFF}}$ input needs to be driven to switch between active and power-down modes. The FORCEON state is not critical because $\overline{\text{FORCEOFF}}$ overrides FORCEON. However, if strictly manual control over power-down is needed, you must strap FORCEON high to disable the automatic powerdown circuitry. The ICL3244E inverting (standard) receiver outputs also disable when the device is in powerdown, and eliminate the possible current path through a shutdown peripheral's input protection diode (see Figures 11 and 12).

Connecting $\overline{\text{FORCEOFF}}$ and FORCEON together disables the enhanced automatic powerdown feature, which enables them to function as a manual $\overline{\text{SHUTDOWN}}$ input (see Figure 13).

With any of the above control schemes, the time required to exit powerdown and resume transmission is only 100µs.

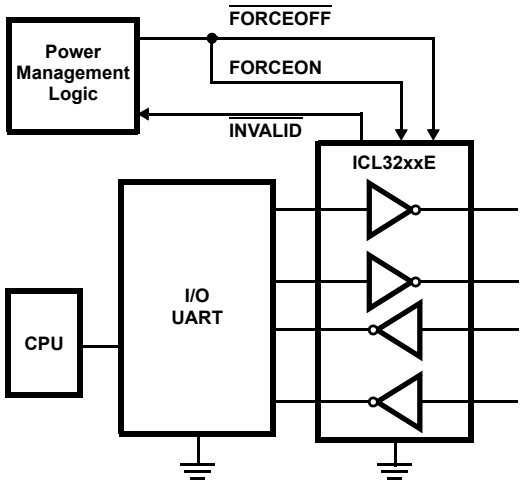


Figure 13. Connections for Manual Powerdown When No Valid Receiver Signals are Present

When using both manual and enhanced automatic powerdown (FORCEON = 0), the ICL32xxE devices do not power up from manual powerdown until both $\overline{\text{FORCEOFF}}$ and FORCEON are driven high, or until a transition occurs on a receiver or transmitter input. Figure 14 shows a circuit for ensuring that the ICL32xxE powers up as soon as $\overline{\text{FORCEOFF}}$ switches high. The rising edge of the master powerdown signal forces the device to power up, and the ICL32xxE returns to enhanced automatic powerdown mode an RC time constant after this rising edge. The time constant is not critical, because the ICL32xxE remains powered up for 30s after the FORCEON falling edge, even if there are no signal transitions. The delay gives slow-to-wake systems (such as a mouse) plenty of time to start transmitting, and as long as it starts transmitting within 30s both systems remain enabled.

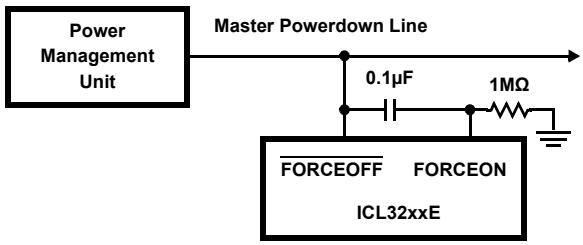


Figure 14. Circuit to Ensure Immediate Power Up When Exiting Forced Powerdown

4.4.2 $\overline{\text{INVALID}}$ Output

Table 5 on page 15 on the $\overline{\text{INVALID}}$ output always indicates whether 30µs have elapsed with invalid RS-232 signals (see Figure 15 and 18) persisting on all of the receiver inputs and provides you a way to determine when

the interface block should power down. Invalid receiver levels occur whenever the driving peripheral's outputs are shut off (powered down) or when the RS-232 interface cable is disconnected. If an interface cable is disconnected and all the receiver inputs are floating (but pulled to GND by the internal receiver pull down resistors), the $\overline{\text{INVALID}}$ logic detects the invalid levels and drives the output low. The power management logic then uses this indicator to power down the interface block. Reconnecting the cable restores valid levels at the receiver inputs, $\overline{\text{INVALID}}$ switches high, and the power management logic wakes up the interface block. $\overline{\text{INVALID}}$ can also indicate the DTR or RING INDICATOR signal, as long as the other receiver inputs are floating, or driven to GND (as in the case of a powered down driver).

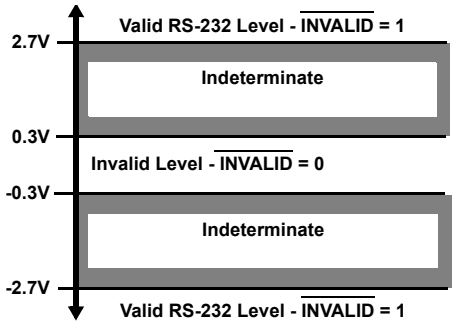


Figure 15. Definition of Valid RS-232 Receiver Levels

4.4.3 Enhanced Automatic Powerdown

Even greater power savings are available by using the ISL32xxE's enhanced automatic powerdown function. When the enhanced powerdown logic determines that no transitions have occurred on any of the transmitter or receiver inputs for 30s, the charge pump and transmitters powerdown, and reduces supply current to 1µA. The ICL32xxE devices automatically power back up whenever they detect a transition on one of these inputs. The automatic powerdown feature provides additional system power savings without changes to the existing operating system.

Enhanced automatic powerdown operates when the FORCEON input is low and the $\overline{\text{FORCEOFF}}$ input is high. Tying FORCEON high disables automatic powerdown, but manual powerdown is always available using the overriding $\overline{\text{FORCEOFF}}$ input. Table 5 on page 15 summarizes the enhanced automatic powerdown functionality.

Figure 16 shows the enhanced powerdown control logic. **Note**: When the ICL32xxE enters powerdown (manually or automatically), the 30s timer remains timed out (set), keeping the ICL32xxE powered down until FORCEON transitions high, or until a transition occurs on a receiver or transmitter input.

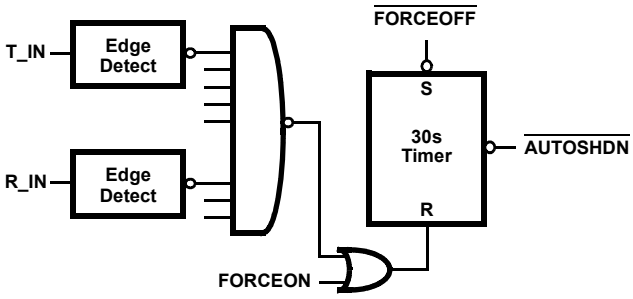


Figure 16. Enhanced Automatic Powerdown Logic

The $\overline{\text{INVALID}}$ output signal switches low to indicate that invalid levels have persisted on all of the receiver inputs for more than 30µs (see Figure 17 on page 18), but this has no direct effect on the state of the ICL32xxE (see the next sections for methods of using $\overline{\text{INVALID}}$ to power down the device). $\overline{\text{INVALID}}$ switches high 1µs after detecting a valid RS-232 level on a receiver input. $\overline{\text{INVALID}}$ operates in all modes (forced or automatic powerdown, or forced on), so it is also useful for systems employing manual powerdown circuitry.

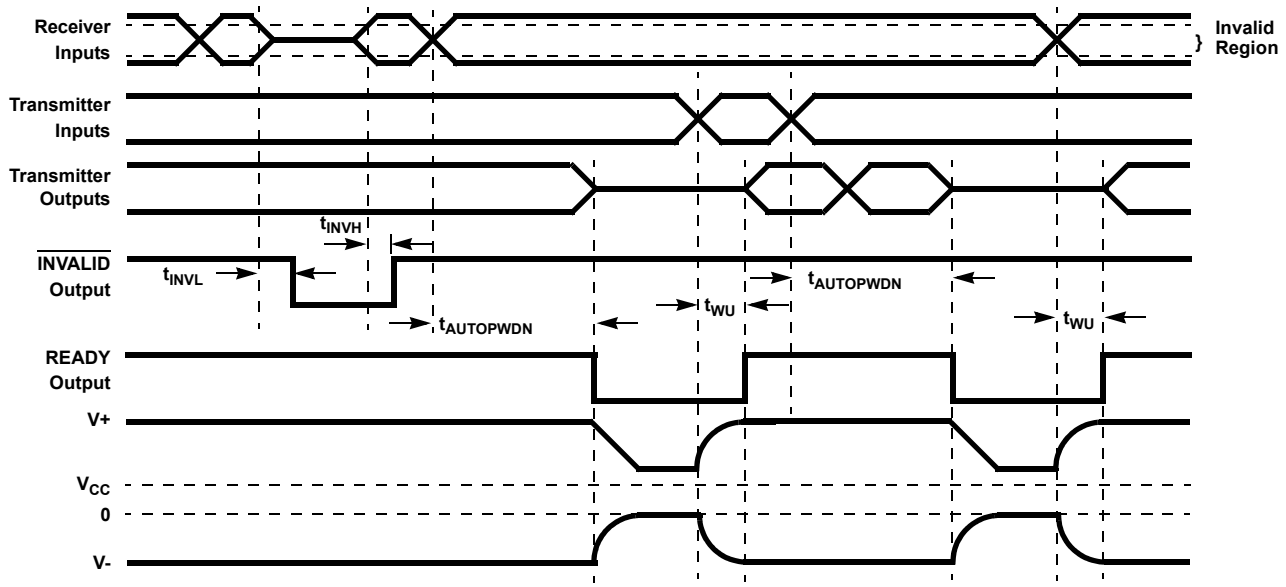


Figure 17. Enhanced Automatic Powerdown, $\overline{\text{INVALID}}$ and READY Timing Diagrams

The time to recover from automatic powerdown mode is typically 100µs.

4.4.4 Emulating Standard Automatic Powerdown

If enhanced automatic powerdown is not desired, you can implement the standard automatic powerdown feature (mimics the function on the ICL3221E/ICL3223E/ICL3243E) by connecting the $\overline{\text{INVALID}}$ output to the FORCEON and $\overline{\text{FORCEOFF}}$ inputs, as shown in Figure 18. After 30µs of invalid receiver levels, $\overline{\text{INVALID}}$ switches low and drives the ICL32xxE into a forced powerdown condition. $\overline{\text{INVALID}}$ switches high as soon as a receiver input senses a valid RS-232 level, forcing the ICL32xxE to power on. See "ICL322XE - INVALID Driving FORCEON and FORCEOFF (Emulates Automatic Powerdown)" on page 15 for an operational summary. This operational mode is perfect for handheld devices that communicate with another computer through a detachable cable. Detaching the cable allows the internal receiver pull-down resistors to pull the inputs to GND (an invalid RS-232 level), causing the 30µs timer to time out and drive the IC into powerdown. Reconnecting the cable restores valid levels, causing the IC to power back up.

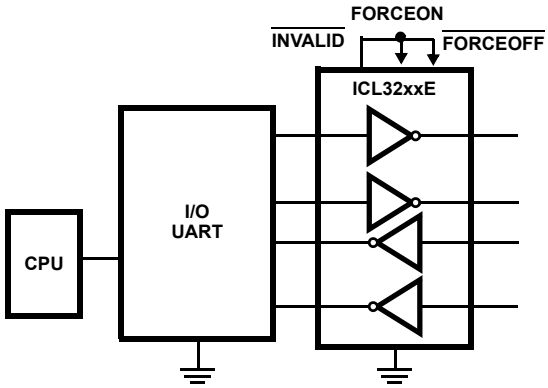


Figure 18. Connections for Automatic Powerdown When No Valid Receiver Signals are Present

4.4.5 Hybrid Automatic Powerdown Options

For devices that communicate only through a detachable cable, you can connect $\overline{\text{INVALID}}$ to $\overline{\text{FORCEOFF}}$ (with FORCEON = 0). While the cable is attached, $\overline{\text{INVALID}}$ and $\overline{\text{FORCEOFF}}$ remain high, so the enhanced automatic powerdown logic powers down the RS-232 device whenever there is 30s of inactivity on the receiver and transmitter inputs. Detaching the cable allows the receiver inputs to drop to an invalid level (GND), so $\overline{\text{INVALID}}$

switches low and forces the RS-232 device to power down. The ICL32xxE remains powered down until the cable is reconnected (INVALID = $\overline{\text{FORCEOFF}}$ = 1), and a transition occurs on a receiver or transmitter input (see Figure 16 on page 17). For immediate power up when the cable is reattached, connect FORCEON to $\overline{\text{FORCEOFF}}$ through a network similar to that shown in Figure 14 on page 16.

4.5 READY Output (ICL3224E and ICL3226E only)

The READY output indicates that the ICL322xE is ready to transmit. READY switches low whenever the device enters powerdown, and switches back high during power-up when V- reaches -4V or lower.

4.6 Capacitor Selection

The charge pumps require 0.1µF capacitors for 3.3V operation. For other supply voltages see to Table 6 for capacitor values. Do not use values smaller than those listed in Table 6. Increasing the capacitor values (by a factor of 2) reduces ripple on the transmitter outputs and slightly reduces power consumption. C_2, C_3, and C_4 can be increased without increasing C_1's value, however, do not increase C_1 without also increasing C_2, C_3, and C_4 to maintain the proper ratios (C_1 to the other capacitors).

When using minimum required capacitor values, make sure that capacitor values do not degrade excessively with temperature. If in doubt, use capacitors with a larger nominal value. The capacitor's Equivalent Series Resistance (ESR) usually rises at low temperatures and it influences the amount of ripple on V+ and V-.

Table 6. Required Capacitor Values

V_{CC} (V)	C_1 (µF)	C_2, C_3, C_4 (µF)
3.0 to 3.6	0.1	0.1
4.5 to 5.5	0.047	0.33
3.0 to 5.5	0.1	0.47

4.7 Power Supply Decoupling

In most circumstances a 0.1µF bypass capacitor is adequate. In applications that are particularly sensitive to power supply noise, decouple V_{CC} to ground with a capacitor of the same value as the charge-pump capacitor C_1. Connect the bypass capacitor as close as possible to the IC.

4.8 Operation Down to 2.7V

ICL32xxE transmitter outputs meet RS-562 levels (±3.7V), at full data rate, with V_{CC} as low as 2.7V. RS-562 levels typically ensure interoperability with RS-232 devices.

4.9 Transmitter Outputs when Exiting Powerdown

Figure 19 on page 20 shows the response of two transmitter outputs when exiting powerdown mode. As they activate, the two transmitter outputs properly go to opposite RS-232 levels, with no glitching, ringing, or undesirable transients. Each transmitter is loaded with 3kΩ in parallel with 2500pF. **Note**: The transmitters enable only when the magnitude of the supplies exceed approximately 3V.

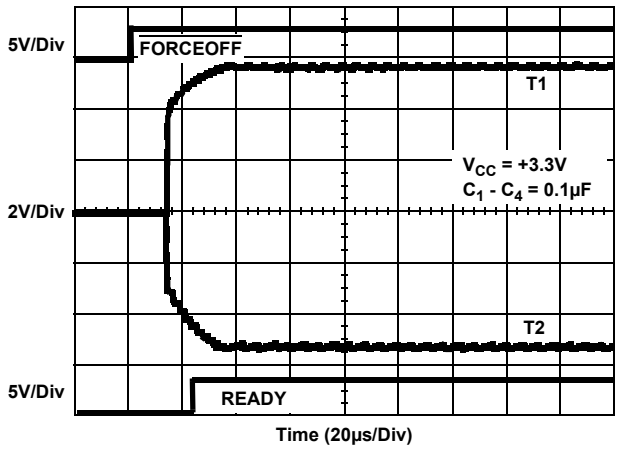


Figure 19. Transmitter Outputs When Exiting Powerdown

4.10 Mouse Driveability

The ICL3244E is specifically designed to power a serial mouse while operating from low voltage supplies. Figure 20 shows the transmitter output voltages under increasing load current. The on-chip switching regulator ensures the transmitters supply at least ±5V during worst case conditions (15mA for paralleled V+ transmitters, 7.3mA for single V- transmitter).

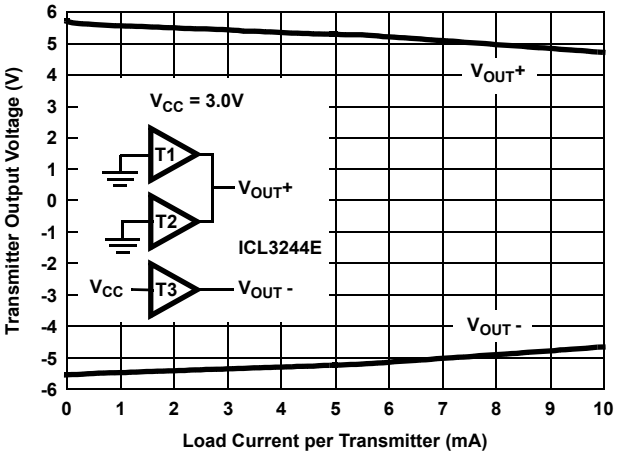


Figure 20. Transmitter Output Voltage vs Load Current (per Transmitter, i.e., Double Current Axis for Total V_{OUT}+ Current)

4.11 High Data Rates

The ICL32xxE maintain the RS-232 ±5V minimum transmitter output voltages even at high data rates. Figure 21 on page 21 shows a transmitter loopback test circuit, and Figure 22 on page 21 shows the loopback test result at 120kbps. For this test, all transmitters were simultaneously driving RS-232 loads in parallel with 1000pF, at 120kbps. Figure 23 on page 21 shows the loopback results for a single transmitter driving 1000pF and an RS-232 load at 250kbps. The static transmitters were also loaded with an RS-232 receiver.

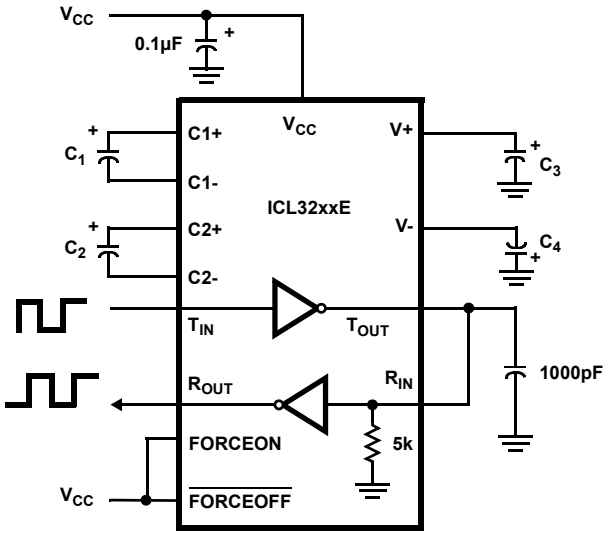


Figure 21. Transmitter Loopback Test Circuit

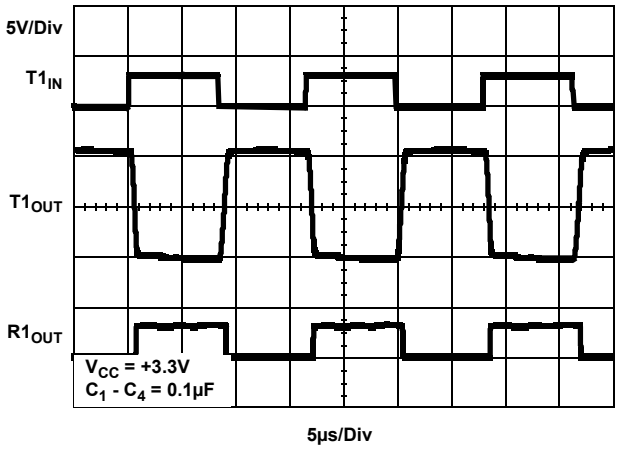


Figure 22. Loopback Test at 120kbps

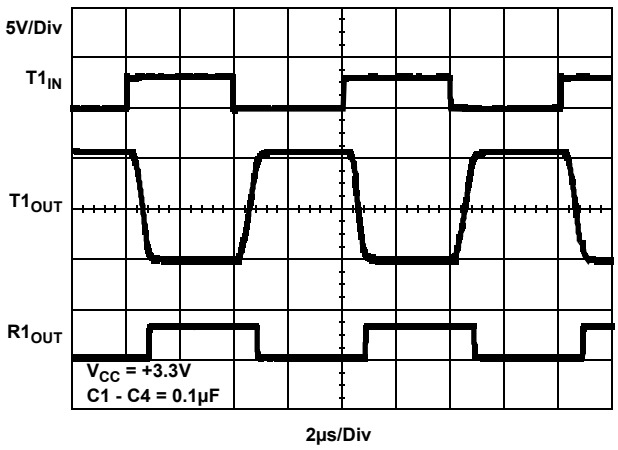


Figure 23. Loopback Test at 250kbps

4.12 Interconnection with 3V and 5V Logic

The ICL32xxE directly interfaces with 5V CMOS and TTL logic families. The AC, HC, and CD4000 outputs can drive the ICL32xxE inputs with the ICL32xxE at 3.3V and the logic supply at 5V, but ICL32xxE outputs do not reach the minimum V_{IH} for these logic families. See Table 7 for more information.

Table 7. Logic Family Compatibility with Various Supply Voltages

System Power-Supply Voltage (V)	V_{CC} Supply Voltage (V)	Compatibility
3.3	3.3	Compatible with all CMOS families.
5	5	Compatible with all TTL and CMOS logic families.
5	3.3	Compatible with ACT and HCT CMOS, and with TTL. ICL32xxE outputs are incompatible with AC, HC, and CD4000 CMOS inputs.

5. ±15kV ESD Protection

All pins on the ICL32xx devices include ESD protection structures, but the ICL32xxE family incorporates advanced structures that allow the RS-232 pins (transmitter outputs and receiver inputs) to survive ESD events up to ±15kV. The RS-232 pins are particularly vulnerable to ESD damage because they typically connect to an exposed port on the exterior of the finished product. Touching the port pins, or connecting a cable, can cause an ESD event that might destroy unprotected ICs. The ESD structures protect the device whether or not it is powered up, protect without allowing any latchup mechanism to activate, and do not interfere with RS-232 signals as large as ±25V.

5.1 Human Body Model (HBM) Testing

The Human Body Model (HBM) test method emulates the ESD event delivered to an IC during human handling. The tester delivers the charge through a 1.5kΩ current limiting resistor, so the test is less severe than the IEC61000 test, which uses a 330Ω limiting resistor. The HBM method determines an IC's ability to withstand the ESD transients typically present during handling and manufacturing. Due to the random nature of these events, each pin is tested with respect to all other pins. The RS-232 pins on "E" family devices can withstand HBM ESD events to ±15kV.

5.2 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-232 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 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-232 pins allows the design of equipment meeting Level 4 criteria without the need for additional board level protection on the RS-232 port.

5.3 Air-gap discharge test method

For the air-gap discharge test, 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 factors such as approach speed, humidity, and temperature, so it is difficult to obtain repeatable results. The "E" device RS-232 pins withstand ±15kV air-gap discharges.

5.4 Contact Discharge Test Method

During the contact discharge test, the probe contacts the tested pin before the probe tip is energized, and eliminates 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 ±8kV. All "E" family devices survive ±8kV contact discharges on the RS-232 pins.

6. Die Characteristics

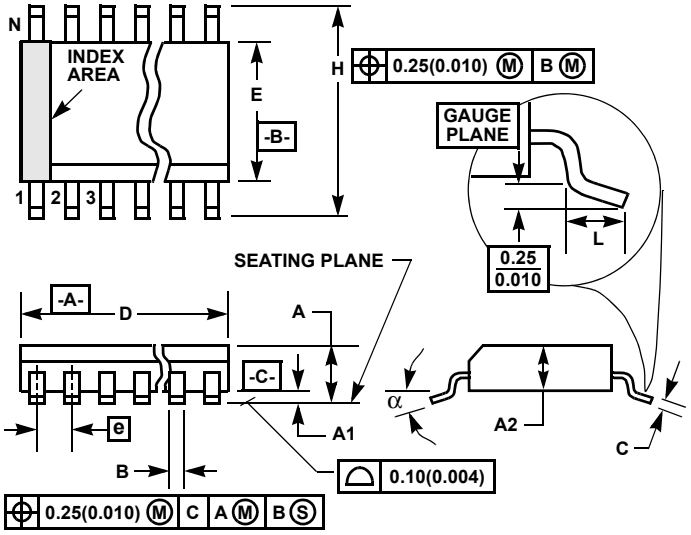
Substrate Potential (Powered Up)	GND
Transistor Count	ISL3224E: 937 ISL3226E: 825 ISL3244E: 1109
Process	Si Gate CMOS

7. Revision History

Rev.	Date	Description
13	Jun.11.19	Updated to latest formatting. Updated Related Literature section. Updated Ordering information table by adding active tape and reel information, added notes 1-3, and removed retired parts. Added “Charge Pump Abs Max Ratings” on page 12. Added Revision History section. Updated disclaimer.

8. Package Outline Drawings

For the most recent package outline drawing, see M16.209.



M16.209 (JEDEC MO-150-AC ISSUE B)
16 Lead Shrink Small Outline Plastic Package (SSOP)

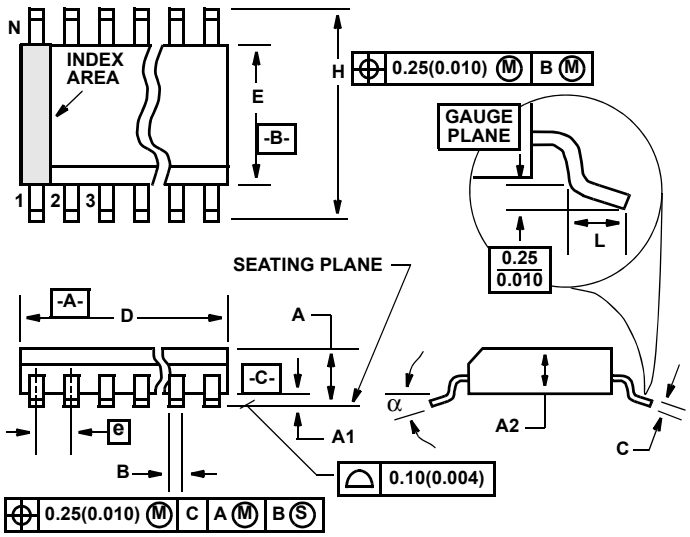
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	-	0.078	-	2.00	-
A1	0.002	-	0.05	-	-
A2	0.065	0.072	1.65	1.85	-
B	0.009	0.014	0.22	0.38	9
C	0.004	0.009	0.09	0.25	-
D	0.233	0.255	5.90	6.50	3
E	0.197	0.220	5.00	5.60	4
e	0.026 BSC		0.65 BSC		-
H	0.292	0.322	7.40	8.20	-
L	0.022	0.037	0.55	0.95	6
N	16		16		7
α	0°	8°	0°	8°	-

Rev. 3 6/05

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 0.20mm (0.0078 inch) per side.
4. Dimension “E” does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.20mm (0.0078 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. Dimension “B” does not include dambar protrusion. Allowable dambar protrusion shall be 0.13mm (0.005 inch) total in excess of “B” dimension at maximum material condition.
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

For the most recent package outline drawing, see M20.209.



M20.209 (JEDEC MO-150-AE ISSUE B)
20 Lead Shrink Small Outline Plastic Package (SSOP)

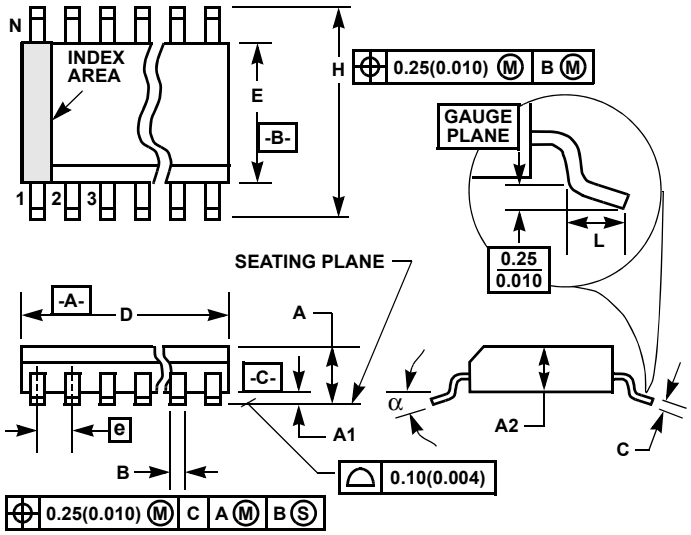
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.068	0.078	1.73	1.99	
A1	0.002	0.008’	0.05	0.21	
A2	0.066	0.070’	1.68	1.78	
B	0.010’	0.015	0.25	0.38	9
C	0.004	0.008	0.09	0.20’	
D	0.278	0.289	7.07	7.33	3
E	0.205	0.212	5.20’	5.38	4
e	0.026 BSC		0.65 BSC		
H	0.301	0.311	7.65	7.90’	
L	0.025	0.037	0.63	0.95	6
N	20		20		7
α	0 deg.	8 deg.	0 deg.	8 deg.	

Rev. 3 11/02

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 0.20mm (0.0078 inch) per side.
4. Dimension “E” does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.20mm (0.0078 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. Dimension “B” does not include dambar protrusion. Allowable dambar protrusion shall be 0.13mm (0.005 inch) total in excess of “B” dimension at maximum material condition.
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

For the most recent package outline drawing, see M28.209.



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 0.20mm (0.0078 inch) per side.
4. Dimension “E” does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.20mm (0.0078 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. Dimension “B” does not include dambar protrusion. Allowable dambar protrusion shall be 0.13mm (0.005 inch) total in excess of “B” dimension at maximum material condition.
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

M28.209 (JEDEC MO-150-AH ISSUE B)
28 Lead Shrink Small Outline Plastic Package (SSOP)

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	-	0.078	-	2.00	-
A1	0.002	-	0.05	-	-
A2	0.065	0.072	1.65	1.85	-
B	0.009	0.014	0.22	0.38	9
C	0.004	0.009	0.09	0.25	-
D	0.390	0.413	9.90	10.50	3
E	0.197	0.220	5.00	5.60	4
e	0.026 BSC		0.65 BSC		-
H	0.292	0.322	7.40	8.20	-
L	0.022	0.037	0.55	0.95	6
N	28		28		7
α	0°	8°	0°	8°	-

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Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

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