Data Sheet | July 13, 2005 | FN4900.8

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

The Intersil ICL32XXE devices are 3.0V to 5.5V powered RS-232 transmitters/receivers which meet EIA/TIA-232 and V.28/V.24 specifications, even at V_{CC} = 3.0V. Additionally, 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, and even lower standby, power consumption is 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 as well. Data rates greater than 1Mbps are guaranteed 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 ICL3245E 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.

These devices, feature an ***enhanced automatic powerdown*** function which powers down the on-chip power-supply and driver circuits. This 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 data sheet, while Application Note AN9863 summarizes the features of each device comprising the ICL32XXE 3V family.

Features

- Pb-Free Plus Anneal Available (RoHS Compliant) (see Ordering Info)
- ESD Protection for RS-232 I/O Pins to ±15kV (IEC61000)
- Manual and Enhanced Automatic Powerdown Features
- Drop in Replacements for MAX3225E, MAX3227E, MAX3245E
- RS-232 Compatible with V_{CC} = 2.7V
- Meets EIA/TIA-232 and V.28/V.24 Specifications at 3V
- Latch-Up Free
- On-Chip Voltage Converters Require Only Four External 0.1µF Capacitors
- Guaranteed Mouse Driveability (ICL3245E)
- “Ready to Transmit” Indicator Output (ICL3225E/ICL3227E)
- Receiver Hysteresis For Improved Noise Immunity
- Guaranteed Minimum Data Rate 1Mbps
- Low Skew at Transmitter/Receiver Input Trip Points . . . 10ns
- Guaranteed Minimum Slew Rate 24V/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

TABLE 1. SUMMARY OF FEATURES

PART NUMBER	NO. OF Tx.	NO. OF Rx.	NO. OF MONITOR Rx. (R_{OUTB})	DATA RATE (kbps)	Rx. ENABLE FUNCTION?	READY OUTPUT?	MANUAL POWER-DOWN?	ENHANCED AUTOMATIC POWERDOWN FUNCTION?
ICL3225E	2	2	0	1000	No	Yes	Yes	Yes
ICL3227E	1	1	0	1000	No	Yes	Yes	Yes
ICL3245E	3	5	1	1000	No	No	Yes	Yes

CAUTION: These devices are sensitive to electrostatic discharge; follow proper IC Handling Procedures.
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Ordering Information

PART NO. *	TEMP. RANGE (°C)	PACKAGE	PKG. DWG. #
ICL3225ECA	0 to 70	20 Ld SSOP	M20.209
ICL3225ECAZ (Note 1)	0 to 70	20 Ld SSOP (Pb-free)	M20.209
ICL3225ECP	0 to 70	20 Ld PDIP	E20.3
ICL3225EIA	-40 to 85	20 Ld SSOP	M20.209
ICL3225EIAZ (Note 1)	-40 to 85	20 Ld SSOP (Pb-free)	M20.209
ICL3227ECA	0 to 70	16 Ld SSOP	M16.209
ICL3227ECAZA (Note 1)	0 to 70	16 Ld SSOP (Pb-free)	M16.209
ICL3227EIA	-40 to 85	16 Ld SSOP	M16.209
ICL3227EIAZA (Note 1)	-40 to 85	16 Ld SSOP (Pb-free)	M16.209
ICL3245ECA	0 to 70	28 Ld SSOP	M28.209
ICL3245ECAZ (Note 1)	0 to 70	28 Ld SSOP (Pb-Free)	M28.209
ICL3245ECB	0 to 70	28 Ld SOIC	M28.3

Ordering Information (Continued)

PART NO. *	TEMP. RANGE (°C)	PACKAGE	PKG. DWG. #
ICL3245ECBZ (Note 1)	0 to 70	28 Ld SOIC (Pb-free)	M28.3
ICL3245ECV	0 to 70	28 Ld TSSOP	M28.173
ICL3245ECVZ (Note 1)	0 to 70	28 Ld TSSOP (Pb-free)	M28.173
ICL3245EIA	-40 to 85	28 Ld SSOP	M28.209
ICL3245EIAZ (Note 1)	-40 to 85	28 Ld SSOP (Pb-free)	M28.209
ICL3245EIB	-40 to 85	28 Ld SOIC	M28.3

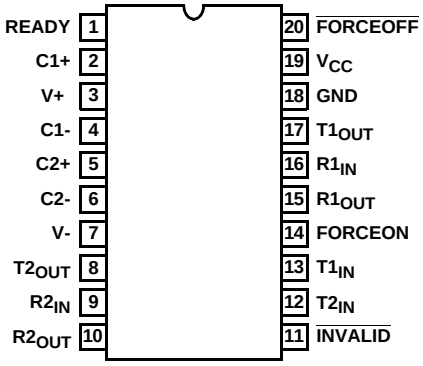
* Most surface mount devices are available on tape and reel; add "-T" to suffix.

NOTE:

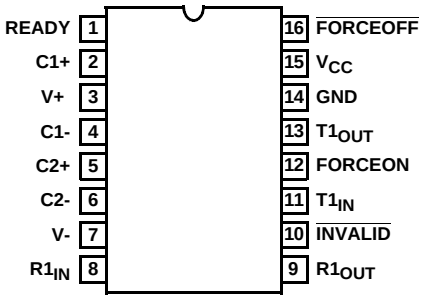
1. Intersil Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free products are MSL classified at Pb-free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

Pinouts

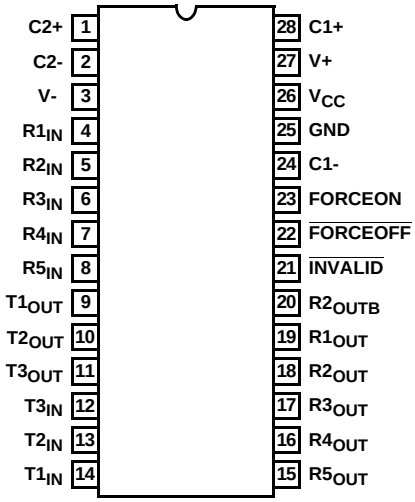
ICL3225E (PDIP, SSOP)
TOP VIEW



ICL3227E (SSOP)
TOP VIEW



ICL3245E (SOIC, SSOP, TSSOP)
TOP VIEW

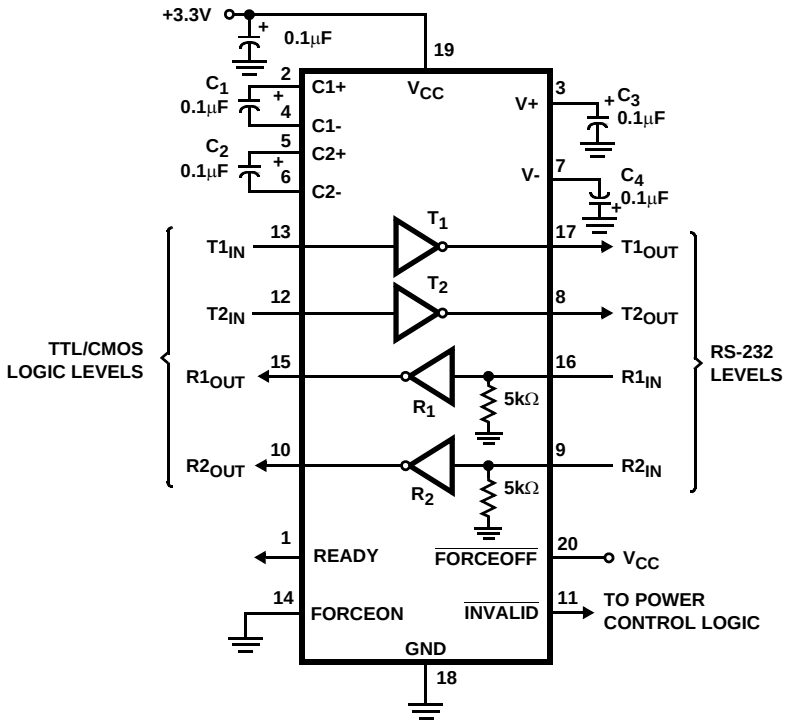


Pin Descriptions

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.
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 (i.e., V- ≤ -4V).
$\overline{\text{FORCEOFF}}$	Active low to shut down transmitters and on-chip power supply. This overrides any automatic circuitry and FORCEON (see Table 2).
FORCEON	Active high input to override automatic powerdown circuitry thereby keeping transmitters active. ($\overline{\text{FORCEOFF}}$ must be high).

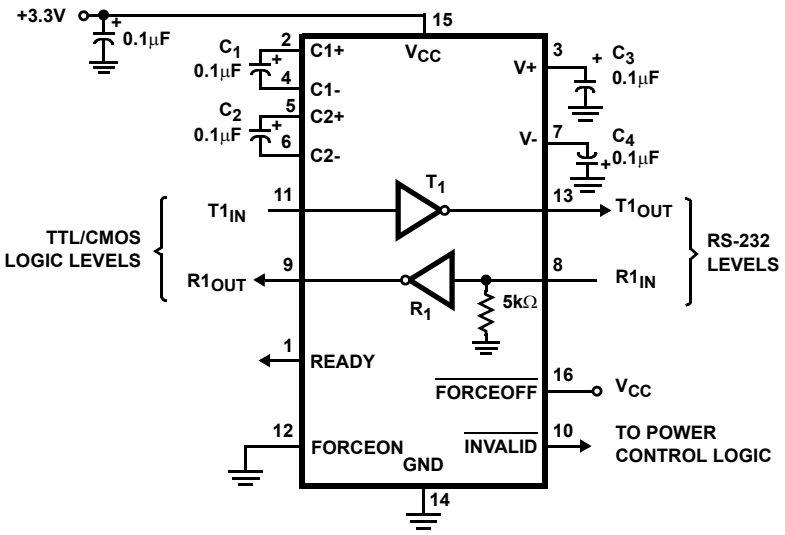
Typical Operating Circuits

ICL3225E

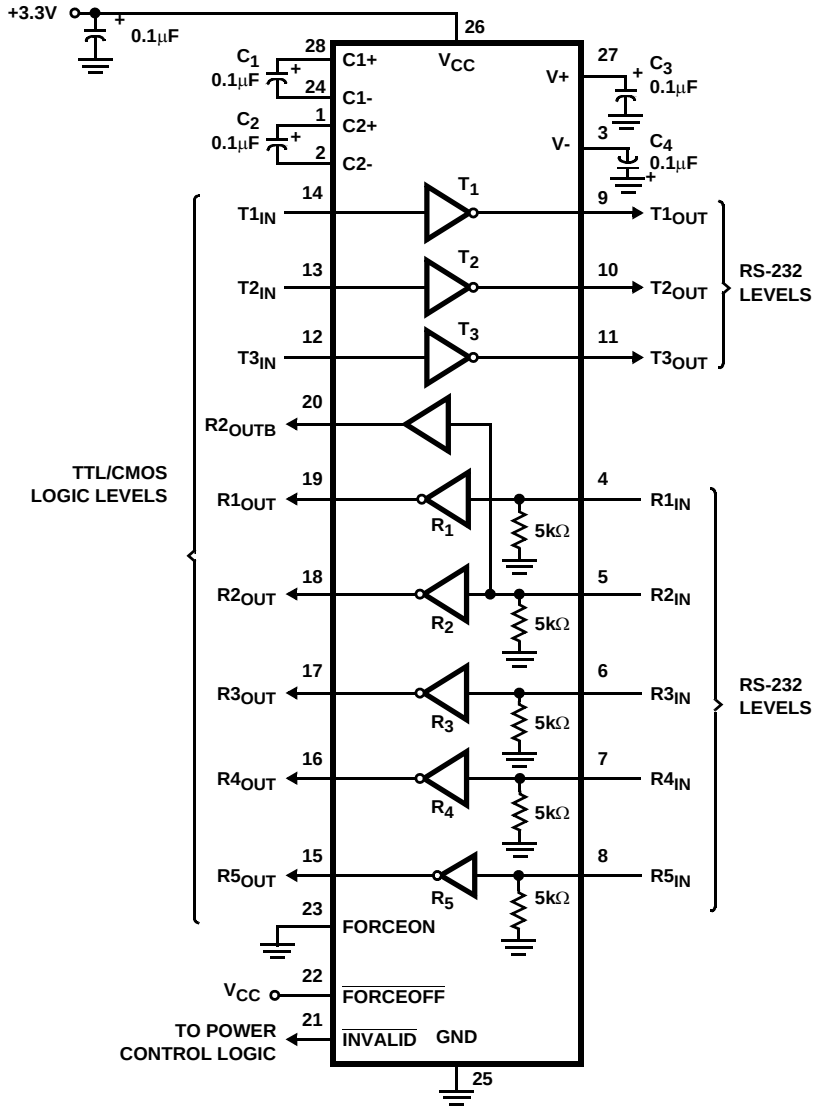


Typical Operating Circuits (Continued)

ICL3227E



ICL3245E



Absolute Maximum Ratings

V_{CC} to Ground . . . . . -0.3V to 6V
V+ to Ground . . . . . -0.3V to 7V
V- to Ground . . . . . +0.3V to -7V
V+ to V- 14V
Input Voltages
T_{IN}, $\overline{FORCEOFF}$, FORCEON . . . . . -0.3V to 6V
R_{IN} . . . . . ±25V
Output Voltages
T_{OUT} . . . . . ±13.2V
R_{OUT}, $\overline{INVALID}$, READY . . . . . -0.3V to V_{CC} +0.3V
Short Circuit Duration
T_{OUT} . . . . . Continuous
ESD Rating . . . . . See Specification Table

Thermal Information

Thermal Resistance (Typical, Note 2)	θ_{JA} (°C/W)
20 Ld PDIP Package	80
28 Ld SOIC Package	75
16 Ld SSOP Package	145
20 Ld SSOP Package	135
28 Ld SSOP and TSSOP Packages	100

Maximum Junction Temperature (Plastic Package) . . . . . 150°C
Maximum Storage Temperature Range . . . . . -65°C to 150°C
Maximum Lead Temperature (Soldering 10s) . . . . . 300°C
(SOIC, SSOP, TSSOP - Lead Tips Only)

Operating Conditions

Temperature Range
ICL32XXEC . . . . . 0°C to 70°C
ICL32XXEI . . . . . -40°C to 85°C

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:

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

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	UNITS
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
Input Leakage Current	T_{IN}, FORCEON, $\overline{FORCEOFF}$		Full	-	±0.01	±1.0	µA
Output Leakage Current	$\overline{FORCEOFF}$ = GND, ICL3245E 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	-	Ω
Output Short-Circuit Current			Full	-	±35	±60	mA

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 **(Continued)**

PARAMETER	TEST CONDITIONS		TEMP (°C)	MIN	TYP	MAX	UNITS
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							
Transmitter Output Voltage (See Figure 11)	$T1_{IN}$ = $T2_{IN}$ = 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 6		Full	-2.7	-	2.7	V
Receiver Input Thresholds to $\overline{INVALID}$ Low	See Figure 6		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
Receiver Positive or Negative Threshold to $\overline{INVALID}$ High Delay (t_{INVH})			25	-	1	-	µs
Receiver Positive or Negative Threshold to $\overline{INVALID}$ Low Delay (t_{INVL})			25	-	30	-	µs
Receiver or Transmitter Edge to Transmitters Enabled Delay (t_{WU})	(Note 3)		25	-	100	-	µs
Receiver or Transmitter Edge to Transmitters Disabled Delay ($t_{AUTOPWDN}$)	(Note 3)		Full	15	30	60	sec
TIMING CHARACTERISTICS							
Maximum Data Rate	R_L = 3kΩ, One Transmitter Switching	C_L = 1000pF	Full	250	-	-	kbps
		V_{CC} = 3V to 4.5V, C_L = 250pF	Full	1000	-	-	kbps
		V_{CC} = 4.5V to 5.5V, C_L = 1000pF	Full	1000	-	-	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 (ICL3245E Only)		25	-	200	-	ns
Receiver Output Disable Time	Normal Operation (ICL3245E Only)		25	-	200	-	ns
Transmitter Skew	t_{PHL} - t_{PLH} (Note 4)		25	-	25	-	ns
Receiver Skew	t_{PHL} - t_{PLH} (Note 4)		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	24	-	150	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		25	-	±3	-	kV

NOTES:

3. An “edge” is defined as a transition through the transmitter or receiver input thresholds.
4. Skews are measured at the receiver input switching points (1.4V).

Detailed Description

These ICL32XXE interface ICs operate from a single +3V to +5.5V supply, guarantee a 1Mbps 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. The circuit is divided into three sections: The charge pump, the transmitters, and the receivers.

Charge-Pump

Intersil's new ICL32XXE family utilizes 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. This 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 3 for capacitor recommendations for other operating conditions. The charge pumps operate discontinuously (i.e., they turn off as soon as the V+ and V- supplies are pumped up to the nominal values), resulting in significant power savings.

Transmitters

The transmitters are proprietary, low dropout, inverting drivers that translate TTL/CMOS inputs to EIA/TIA-232 output levels. Coupled with the on-chip ±5.5V supplies, these transmitters 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 2). These outputs may be driven to ±12V when disabled.

All devices guarantee a 1Mbps data rate for full load conditions (3kΩ and 250pF), $V_{CC} \geq 3.0V$, 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 1.4Mbps. Transmitter skew is extremely low on these devices, and is specified at the receiver input trip points (1.4V), rather than the arbitrary 0V crossing point typical of other RS-232 families.

Transmitter inputs float if left unconnected, and may cause I_{CC} increases. Connect unused inputs to GND for the best performance.

Receivers

All the ICL32XXE devices contain standard inverting receivers, but only the ICL3245E receivers can tristate, via the $\overline{FORCEOFF}$ control line. Additionally, the ICL3245E 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 1) 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.

The ICL3245E inverting receivers disable during forced (manual) powerdown, but not during automatic powerdown (see Table 2). Conversely, the monitor receiver remains active even during manual powerdown making 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 2 and 3). This renders them useless for wake up functions, but the corresponding monitor receiver can be dedicated to this task as shown in Figure 3.

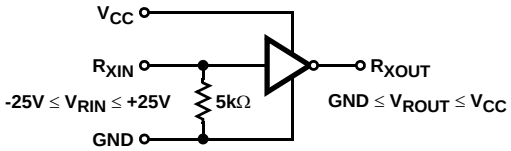


FIGURE 1. INVERTING RECEIVER CONNECTIONS

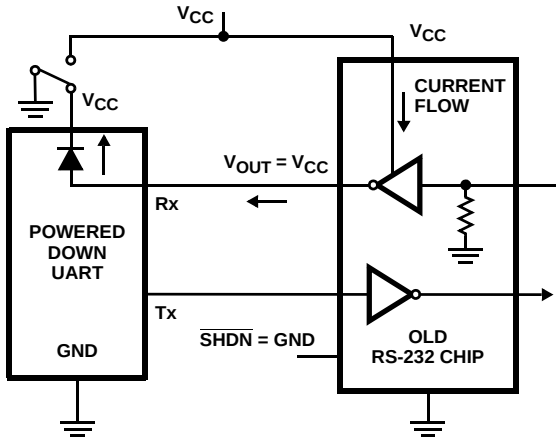


FIGURE 2. POWER DRAIN THROUGH POWERED DOWN PERIPHERAL

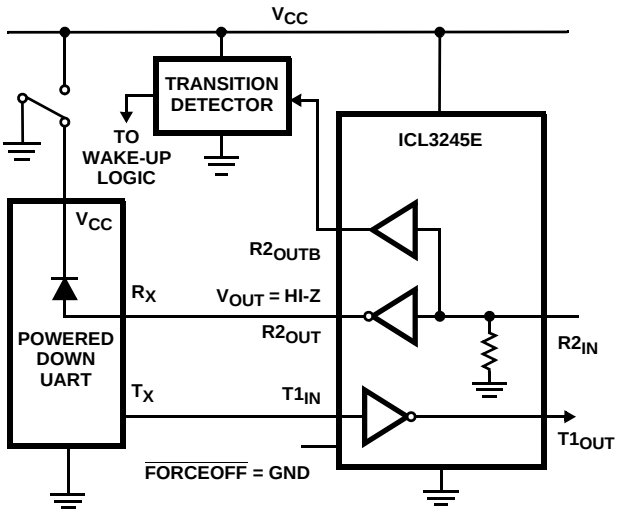


FIGURE 3. DISABLED RECEIVERS PREVENT POWER DRAIN

TABLE 2. POWERDOWN LOGIC TRUTH TABLE

RCVR OR XMTR EDGE WITHIN 30 SEC?	$\overline{\text{FORCEOFF}}$ INPUT	FORCEON INPUT	TRANSMITTER OUTPUTS	RECEIVER OUTPUTS	(NOTE 5) R_{OUTB} OUTPUTS	RS-232 LEVEL PRESENT AT RECEIVER INPUT?	$\overline{\text{INVALID}}$ OUTPUT	MODE OF OPERATION
ICL3225E, ICL3227E								
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 6	NOTE 6	Active	Active	N.A.	Yes	H	Normal Operation
X	NOTE 6	NOTE 6	High-Z	Active	N.A.	No	L	Forced Auto Powerdown
ICL3245E								
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	
ICL3245E - $\overline{\text{INVALID}}$ DRIVING FORCEON AND $\overline{\text{FORCEOFF}}$ (EMULATES AUTOMATIC POWERDOWN)								
X	NOTE 6	NOTE 6	Active	Active	Active	Yes	H	Normal Operation
X	NOTE 6	NOTE 6	High-Z	High-Z	Active	No	L	Forced Auto Powerdown

NOTES:

5. Applies only to the ICL3245E.
6. Input is connected to $\overline{\text{INVALID}}$ Output.

Powerdown Functionality

This 3V family of RS-232 interface devices requires a nominal supply current of 0.3mA during normal operation (not in powerdown mode). This 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 tristate. Inverting receiver outputs may or may not disable in powerdown; refer to Table 2 for details. This micro-power mode makes these devices ideal for battery powered and portable applications.

Software Controlled (Manual) Powerdown

These three devices allow the user to force the IC into the low power, standby state, and utilize 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. To switch between active and powerdown modes, under logic or software control, only the $\overline{\text{FORCEOFF}}$ input need be driven. The FORCEON state isn't critical, as $\overline{\text{FORCEOFF}}$ dominates over FORCEON. Nevertheless, if strictly manual control over powerdown is desired, the user must strap FORCEON high to disable the enhanced automatic powerdown circuitry. ICL3245E inverting (standard) receiver outputs also disable when the device is in powerdown, thereby eliminating the possible current path through a shutdown peripheral's input protection diode (see Figures 2 and 3).

Connecting $\overline{\text{FORCEOFF}}$ and FORCEON together disables the enhanced automatic powerdown feature, enabling them to function as a manual $\overline{\text{SHUTDOWN}}$ input (see Figure 4).

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

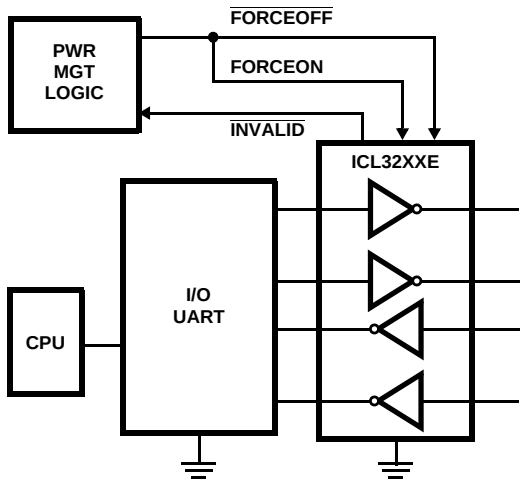


FIGURE 4. CONNECTIONS FOR MANUAL POWERDOWN WHEN NO VALID RECEIVER SIGNALS ARE PRESENT

When using both manual and enhanced automatic powerdown (FORCEON = 0), the ICL32XXE won't 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 5 illustrates 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 isn't critical, because the ICL32XXE remains powered up for 30 seconds after the FORCEON falling edge, even if there are no signal transitions. This gives slow-to-wake systems (e.g., a mouse) plenty of time to start transmitting, and as long as it starts transmitting within 30 seconds both systems remain enabled.

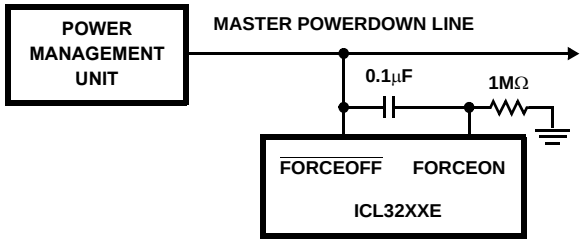


FIGURE 5. CIRCUIT TO ENSURE IMMEDIATE POWER UP WHEN EXITING FORCED POWERDOWN

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

The $\overline{\text{INVALID}}$ output always indicates (see Table 2) whether or not 30µs have elapsed with invalid RS-232 signals (see Figures 6 and 8) persisting on all of the receiver inputs, giving the user an easy 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. In the case of a disconnected interface cable where 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 be used to 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).

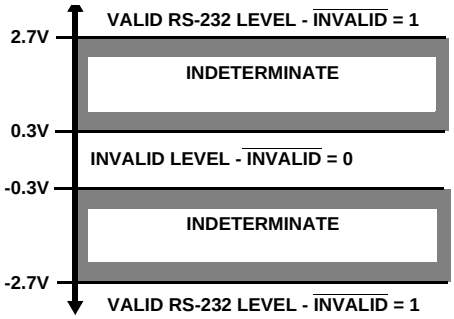


FIGURE 6. DEFINITION OF VALID RS-232 RECEIVER LEVELS

Enhanced Automatic Powerdown

Even greater power savings is available by using these devices which feature an *enhanced automatic* powerdown function. When the enhanced powerdown logic determines that no transitions have occurred on any of the transmitter nor receiver inputs for 30 seconds, the charge pump and transmitters powerdown, thereby reducing supply current to 1µA. The ICL32XXE automatically powers back up whenever it detects a transition on one of these inputs. This 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 via the overriding $\overline{\text{FORCEOFF}}$ input. Table 2 summarizes the enhanced automatic powerdown functionality.

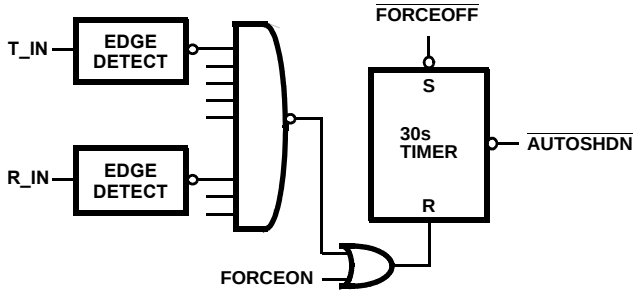


FIGURE 7. ENHANCED AUTOMATIC POWERDOWN LOGIC

Figure 7 illustrates the enhanced powerdown control logic. Note that once the ICL32XXE enters powerdown (manually or automatically), the 30 second 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.

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 8), but this has no direct effect on the state of the ICL32XXE (see the next sections for methods of utilizing $\overline{\text{INVALID}}$ 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.

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

Emulating Standard Automatic Powerdown

If enhanced automatic powerdown isn't desired, the user 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 9. 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 the "$\overline{\text{INVALID}}$ DRIVING FORCEON AND $\overline{\text{FORCEOFF}}$" section of Table 2 for an operational summary. This operational mode is perfect for handheld devices that communicate with another computer via 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.

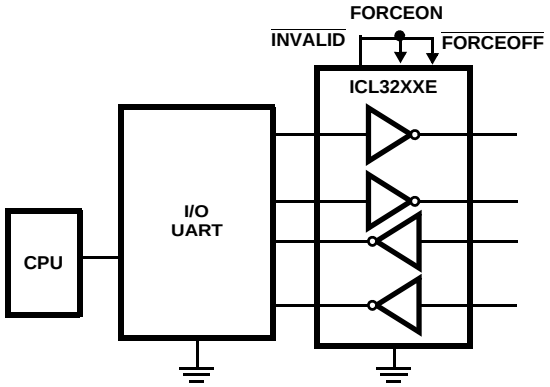


FIGURE 8. CONNECTIONS FOR AUTOMATIC POWERDOWN WHEN NO VALID RECEIVER SIGNALS ARE PRESENT

Hybrid Automatic Powerdown Options

For devices which communicate only through a detachable cable, connecting $\overline{\text{INVALID}}$ to $\overline{\text{FORCEOFF}}$ (with FORCEON = 0) may be a desirable configuration. 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 30 seconds 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 ($\overline{\text{INVALID}}$ = $\overline{\text{FORCEOFF}}$ = 1) and a transition occurs on a receiver or transmitter input (see Figure 7). For immediate power up when the cable is reattached, connect FORCEON to $\overline{\text{FORCEOFF}}$ through a network similar to that shown in Figure 5.

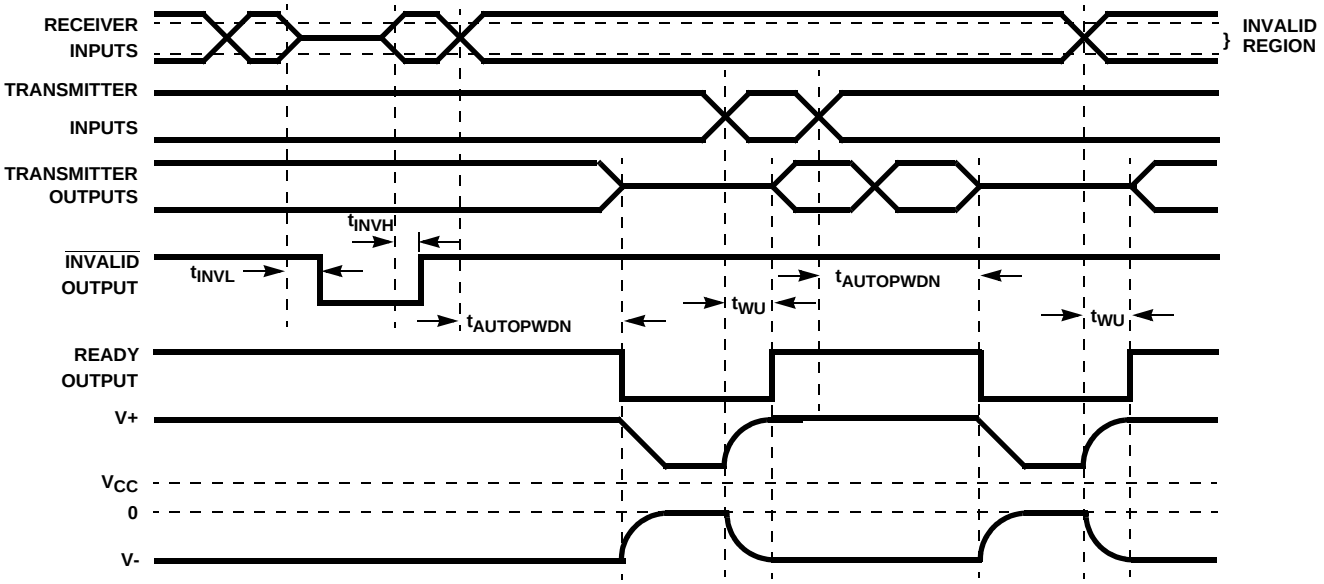


FIGURE 9. ENHANCED AUTOMATIC POWERDOWN, $\overline{\text{INVALID}}$ AND READY TIMING DIAGRAMS