+5V, 1µA, Single RS-232 Transceiver with AutoShutdown

ABSOLUTE MAXIMUM RATINGS

V_{CC} .....-0.3V to +6V
V+ .....(V_{CC} - 0.3V) to +14V
V- .....-14V to +0.3V
Input Voltages
TIN .....-0.3V to (V+ + 0.3V)
RIN .....±30V
FORCEON, $\overline{FORCEOFF}$, $\overline{EN}$.....-0.3V to (V_{CC} + 0.3V)
Output Voltages
TOUT .....(V- - 0.3V) to (V+ + 0.3V)
ROUT, $\overline{INVALID}$.....-0.3V to (V_{CC} + 0.3V)

Short-Circuit Duration, TOUT .....Continuous
Continuous Power Dissipation (T_A = +70°C)
TSSOP (derated 6.7mW/°C above +70°C) 533mW
SSOP (derated 7.1mW/°C above +70°C) 571mW
Operating Temperature Range
MAX221C_ _ .....0°C to +70°C
MAX221E_ _ .....-40°C to +85°C
Maximum Junction Temperature ..... +150°C
Storage Temperature Range ..... -65°C to +150°C
Lead Temperature (soldering, 10sec) ..... +300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DC CHARACTERISTICS							
V_{CC} Supply Current	I_{CC}	No load, T_A = +25°C			5	10	mA
Shutdown Supply Current	I_{SHDN}	T_A = +25°C, Figure 1			1	10	µA
AutoShutdown Supply Current	I_{AS}				1	10	µA
LOGIC INPUTS							
Input Leakage Current	I_{IN}	TIN = 0 to V_{CC}				±1	µA
Input Threshold Low	V_{IL}	TIN; $\overline{EN}$, $\overline{FORCEOFF}$, FORCEON				0.8	V
Input Threshold High	V_{IH}	TIN, $\overline{EN}$, $\overline{FORCEOFF}$		2.4			V
Output Voltage Low	V_{OL}	ROUT; I_{SINK} = 3.2mA				0.4	V
Output Voltage High	V_{OH}	ROUT; I_{SOURCE} = 1.0mA		3.5			V
Output Leakage Current		$\overline{EN}$ = V_{CC}, 0 ≤ ROUT ≤ V_{CC}			±0.05	±10	µA
AUTOSHUTDOWN							
Receiver Input Threshold, Transmitter Enabled		Figure 3	Positive threshold			2.7	V
			Negative threshold	-2.7			
Receiver Input Threshold, Transmitter Disabled		I_{CC} = 1µA, Figure 3		-0.3		0.3	V
$\overline{INVALID}$ Output Voltage Low		I_{SINK} = 1.6mA				0.4	V
$\overline{INVALID}$ Output Voltage High		I_{SOURCE} = 1.0mA		V_{CC} - 0.6			V
Receiver Threshold to Transmitter Enabled	t_{WU}	Figure 3			250		µs
Receiver Positive or Negative Threshold to $\overline{INVALID}$ High	t_{INVH}	Figure 3			1		µs
Receiver Positive or Negative Threshold to $\overline{INVALID}$ Low	t_{INVL}	Figure 3			30		µs

ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
RECEIVER INPUT						
Input Voltage Range			-25		25	V
Input Threshold Low		T_A = +25°C, V_{CC} = 5V	0.8	1.2		V
Input Threshold High		T_A = +25°C, V_{CC} = 5V		1.7	2.4	V
Input Hysteresis		V_{CC} = 5V, no hysteresis in shutdown		0.5		V
Input Resistance		T_A = +25°C, V_{CC} = 5V	3	5	7	kΩ
TRANSMITTER OUTPUT						
Output Voltage Swing		Driver loaded with 3kΩ to ground	±5	±9		V
Output Resistance		V_{CC} = V+ = V- = 0, V_{OUT} = ±2V	300			Ω
Output Short-Circuit Current				±10	±60	mA

TIMING CHARACTERISTICS

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Maximum Data Rate		R_L = 3kΩ to 7kΩ, C_L = 50pF to 1000pF, V_{CC} = 4.5V	250			kbps
Receiver Propagation Delay	t_{PHL}, t_{PLH}	C_L = 150pF		0.15		µs
Receiver Output Enable Time		Normal operation		300		ns
Receiver Output Disable Time		Normal operation		200		ns
Transmitter Skew	$\lvert t_{PHL} - t_{PLH} \rvert$	(Note 1)		200		ns
Receiver Skew	$\lvert t_{PHL} - t_{PLH} \rvert$			50		ns
Transition-Region Slew Rate		T_A = +25°C, V_{CC} = 5V, R_L = 3kΩ to 7kΩ, C_L = 500pF to 1000pF, measured from -3V to +3V or +3V to -3V	3	6	30	V/µs

Note 1: Transmitter skew is measured at the transmitter zero crosspoints.

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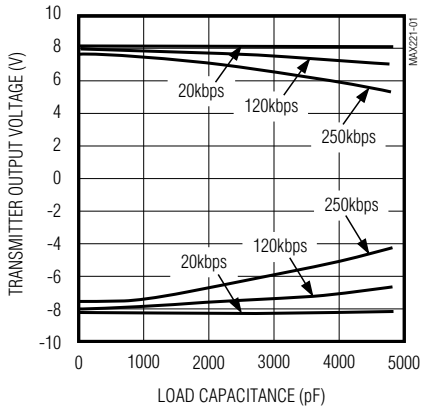
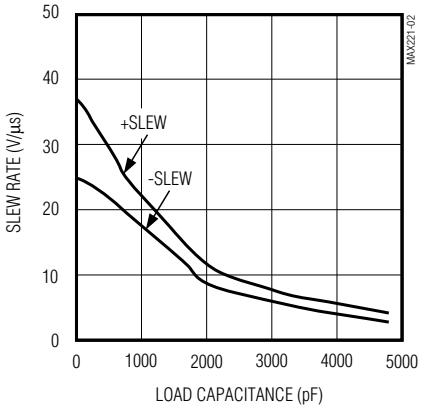
Typical Operating Characteristics

(V_{CC} = +5V, 250kbps data rate, 0.1µF capacitors, transmitter loaded with 3kΩ and C_L, T_A = +25°C, unless otherwise noted.)

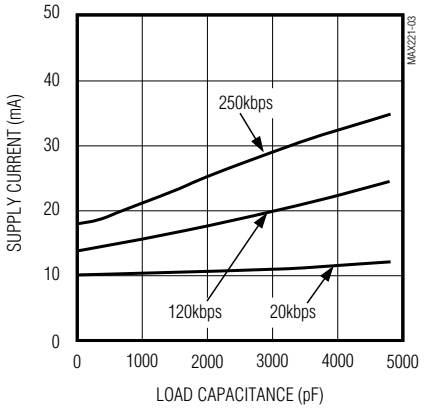
TRANSMITTER OUTPUT VOLTAGE vs. LOAD CAPACITANCE



SLEW RATE vs. LOAD CAPACITANCE



OPERATING SUPPLY CURRENT vs. LOAD CAPACITANCE



Pin Description

PIN	NAME	FUNCTION
1	$\overline{EN}$	Receiver Enable Control. Drive low for normal operation. Drive high to force the receiver output (ROUT) into a high-impedance state.
2	C1+	Positive Terminal of the Voltage Doubler Charge-Pump Capacitor
3	V+	Positive Voltage Generated by the Charge Pump
4	C1-	Negative Terminal of the Voltage Doubler Charge-Pump Capacitor
5	C2+	Positive Terminal of the Inverting Charge-Pump Capacitor
6	C2-	Negative Terminal of the Inverting Charge-Pump Capacitor
7	V-	Negative Voltage Generated by the Charge Pump
8	RIN	RS-232 Receiver Input
9	ROUT	TTL/CMOS Receiver Output
10	$\overline{INVALID}$	Output of the Invalid Signal Detector. $\overline{INVALID}$ is pulled low if no valid RS-232 level is present on the receiver input.
11	TIN	TTL/CMOS Transmitter Input
12	FORCEON	Drive high to override automatic circuitry, keeping transmitter and charge pump on. $\overline{FORCEOFF}$ must be high (Table 1).
13	TOUT	RS-232 Transmitter Output
14	GND	Ground
15	V_{CC}	+4.5V to +5.5V Supply Voltage
16	$\overline{FORCEOFF}$	Force-Off Input, active low. Drive low to shut down transmitter, receiver, and on-board charge pump. This overrides all automatic circuitry and FORCEON (Table 1).

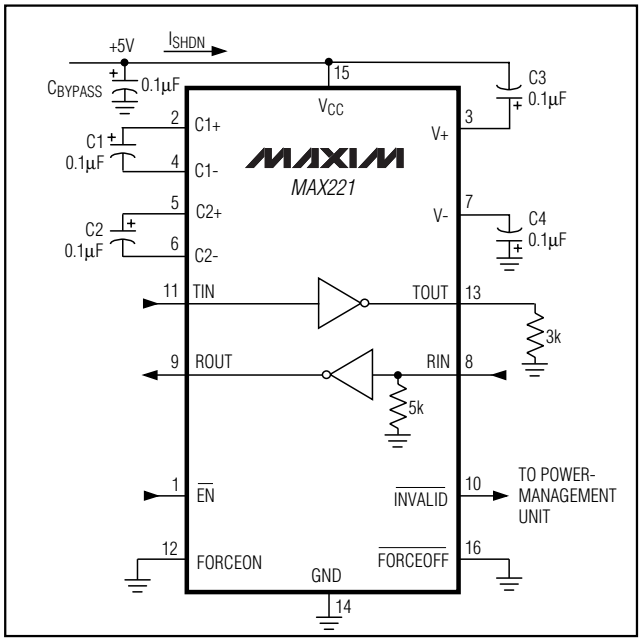


Figure 1. Shutdown Current Test Circuit

Detailed Description

Dual Charge-Pump Voltage Converter

The MAX221's internal power supply consists of a dual charge pump that provides a positive output voltage (doubling charge pump) and a negative voltage (inverting charge pump) from a single +5V supply. The charge pumps operate in continuous mode. Each charge pump requires a flying capacitor (C1, C2) and a reservoir capacitor (C3, C4) to generate the V+ and V- supplies.

RS-232 Transmitter

The transmitter is an inverting level translator that converts CMOS-logic levels to 5.0V EIA/TIA-232 levels. It guarantees a 250kbps data rate with worst-case loads of 3kΩ in parallel with 1000pF.

When $\overline{\text{FORCEOFF}}$ is driven to ground, or when the AutoShutdown circuitry senses invalid voltage levels on the receiver input, the transmitter is disabled and the output is forced into a high-impedance state. The transmitter input does not have a pull-up resistor.

RS-232 Receiver

The MAX221's receiver converts RS-232 signals to CMOS-logic output levels. The receiver has an inverting three-state output and can be active or inactive. In shutdown ($\overline{\text{FORCEOFF}}$ = low) or in AutoShutdown, the receiver is active (Table 1). Drive $\overline{\text{EN}}$ high to place the receiver in a high-impedance state. The receiver is high impedance when the MAX221 is in shutdown ($\overline{\text{FORCEOFF}}$ = low).

The MAX221's $\overline{\text{INVALID}}$ output is pulled low when no valid RS-232 signal level is detected on the receiver input. $\overline{\text{INVALID}}$ is functional in any mode (Figures 2 and 3).

AutoShutdown

The MAX221 achieves 1µA supply current with Maxim's AutoShutdown feature, which operates when FORCEON is low and $\overline{\text{FORCEOFF}}$ is high. When the device senses no valid signal levels on the receiver input for 30µs, the on-board charge pump and driver are shut off, reducing supply current to 1µA. This occurs if the RS-232 cable is disconnected or the connected peripheral transmitter is turned off. The MAX221 turns on again when a valid level is applied to the RS-232 receiver input. As a result, the system saves power without changes to the existing BIOS or operating system.

Table 1 and Figure 2c summarize the MAX221 operating modes. FORCEON and $\overline{\text{FORCEOFF}}$ override AutoShutdown. When neither control is asserted, the device selects between these states automatically, based on the receiver input level. Figures 2a, 2b, and 3a depict valid and invalid RS-232 receiver levels. Figure 3 shows the input levels and timing diagram for AutoShutdown operation.

A device or another system with AutoShutdown connected to the MAX221 may need time to wake up. Figure 4 shows a circuit that forces the transmitter on for 100ms, allowing enough time for the other system to realize that the MAX221 is awake. If the other system transmits valid RS-232 signals within that time, the RS-232 ports on both systems remain enabled.

When shut down, the device's charge pumps are off, V+ is pulled to V_{CC}, V- is pulled to ground, and the transmitter output is high impedance. The time required to exit shutdown is typically 100µs (Figure 3b).

Software-Controlled Shutdown

For direct software control, use $\overline{\text{INVALID}}$ to indicate a DTR or Ring Indicator signal. Connect $\overline{\text{FORCEOFF}}$ and FORCEON together to disable AutoShutdown so the line acts like a $\overline{\text{SHDN}}$ input.

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Table 1. Output Control Truth Table

OPERATION STATUS	FORCEON	$\overline{\text{FORCEOFF}}$	$\overline{\text{EN}}$	VALID RECEIVER LEVEL	TOUT	ROUT
Shutdown (Forced Off)	X	0	0	X	High-Z	Active
	X	0	1	X	High-Z	High-Z
Normal Operation (Forced On)	1	1	0	X	Active	Active
	1	1	1	X	Active	High-Z
Normal Operation (AutoShutdown)	0	1	0	Yes	Active	Active
	0	1	1	Yes	Active	High-Z
Shutdown (AutoShutdown)	0	1	0	No	High-Z	Active
	0	1	1	No	High-Z	High-Z

X = Don't care

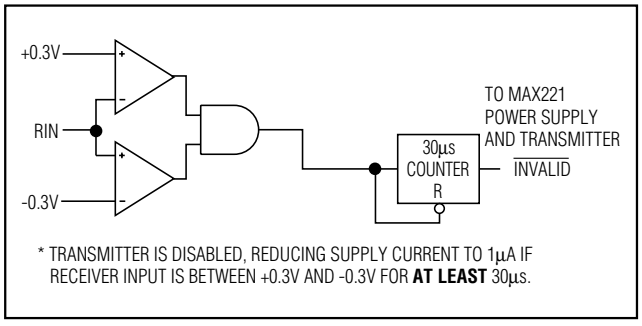

Figure 2a. Entering 1µA Supply Mode via AutoShutdown

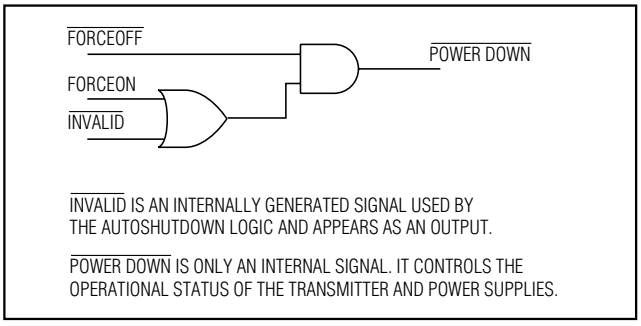

Figure 2c. AutoShutdown Logic

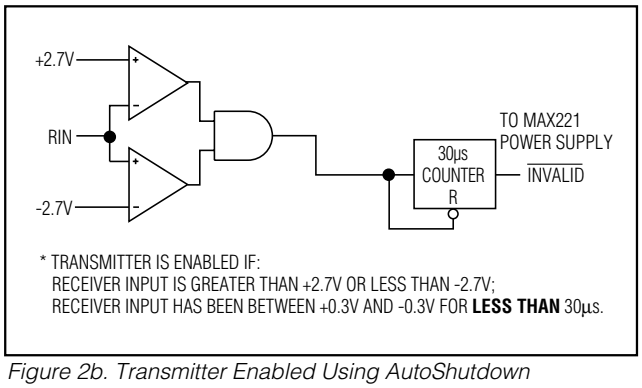

Figure 2b. Transmitter Enabled Using AutoShutdown

Table 2. $\overline{\text{INVALID}}$ Truth Table

RS-232 SIGNAL PRESENT AT RECEIVER INPUT	$\overline{\text{INVALID}}$ OUTPUT
Yes	High
No	Low

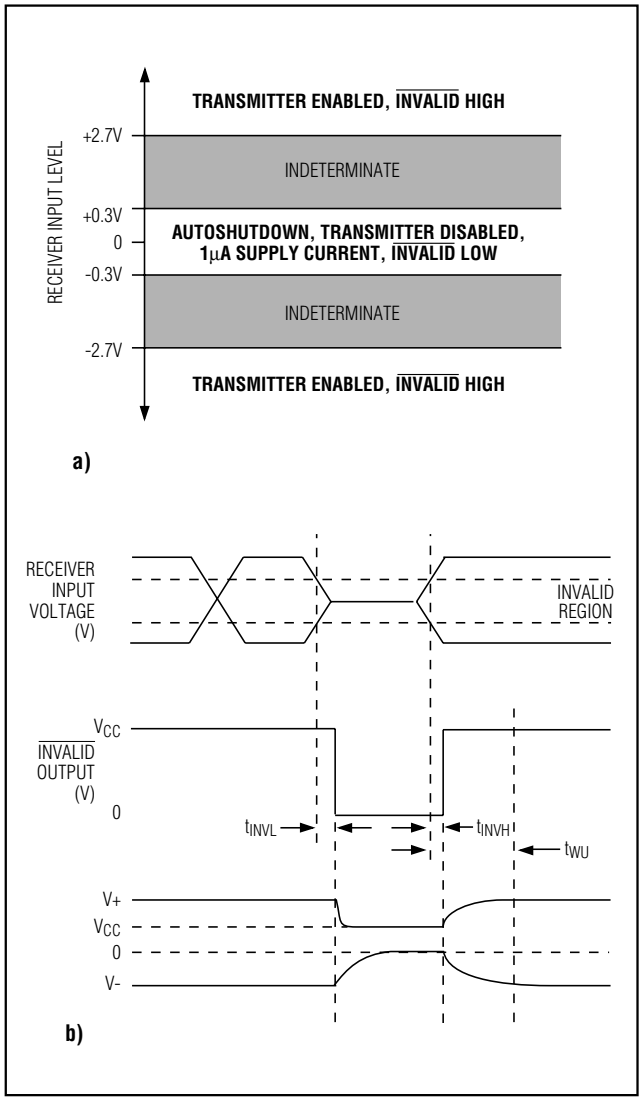

Figure 3. AutoShutdown Trip Levels

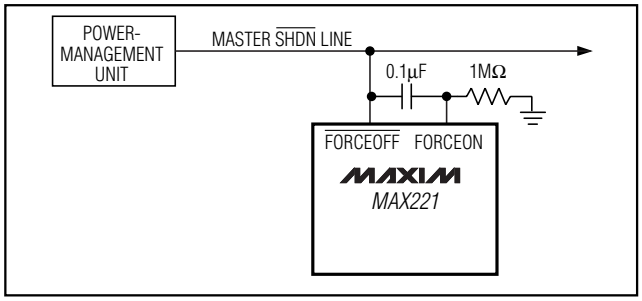

Figure 4. AutoShutdown with Initial Turn-On to Wake Up a Mouse or Another System

Applications Information

Using INVALID

INVALID indicates when an RS-232 signal is present at the receiver input, and therefore when the port is in use. INVALID can be used in alternative shutdown control schemes where it relieves the processor from constantly polling the port for activity.

Capacitor Selection

The capacitor type used for C1–C4 is not critical for proper operation; either polarized or nonpolarized capacitors are acceptable. If polarized capacitors are used, connect polarity as shown in the *Typical Operating Circuit*. The charge pump requires 0.1µF capacitors. Increasing the capacitor values (e.g., by a factor of 2) reduces ripple on the transmitter output and slightly reduces power consumption. C2, C3, and C4 can be increased without changing C1's value. However, do not increase C1's value without also increasing the values of C2, C3, and C4 to maintain the proper ratios (C1 to the other capacitors).

When using the minimum 0.1µF capacitors, make sure the capacitance does 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 influences the amount of ripple on V+ and V-.

Power-Supply Decoupling

In most circumstances, a 0.1µF V_{CC} bypass capacitor is adequate. In applications that are sensitive to power-supply noise, use a capacitor of the same value as the charge-pump capacitor C1. Connect bypass capacitors as close to the IC as possible.

Transmitter Output when Exiting Shutdown

Figure 5 shows the transmitter output when exiting shutdown mode. The transmitter is loaded with 3kΩ in parallel with 2500pF. The transmitter output displays no ringing or undesirable transients as the MAX221 comes out of shutdown. Note that the transmitter is enabled only when the magnitude of V- exceeds approximately 3V.

High Data Rates

The MAX221 maintains the RS-232 ±5.0V minimum transmitter output voltage even at high data rates. Figure 6 shows a transmitter loopback test circuit. Figure 7 shows the loopback test result at 120kbps, and Figure 8 shows the same test at 250kbps.

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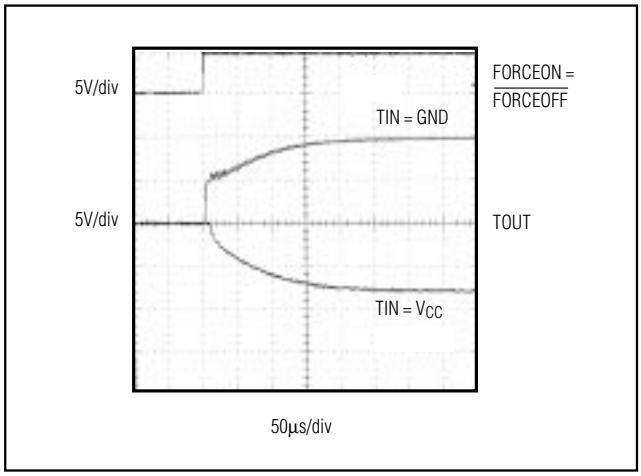

Figure 5. Transmitter Output Exiting Shutdown or Powering Up

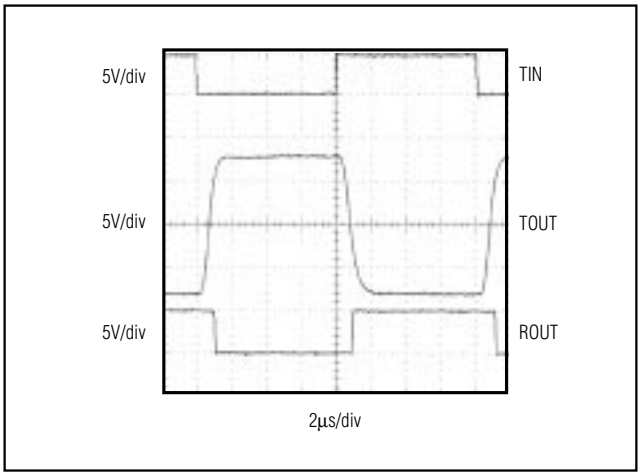

Figure 7. Loopback Test Result at 120kbps

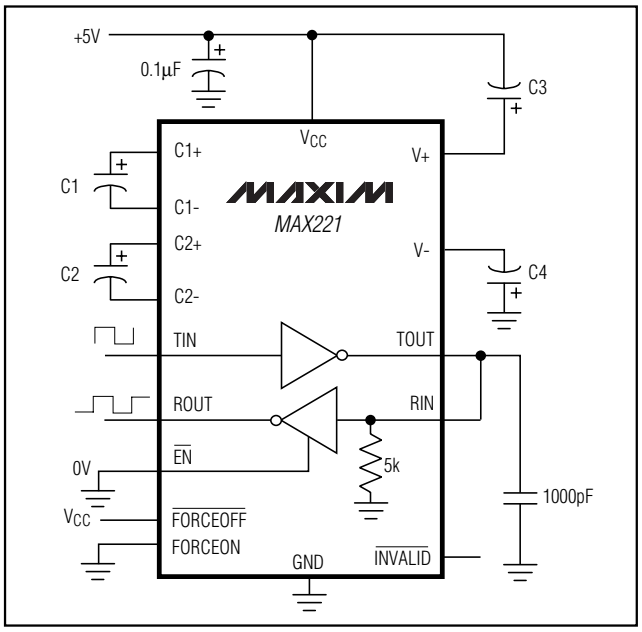

Figure 6. Loopback Test Circuit

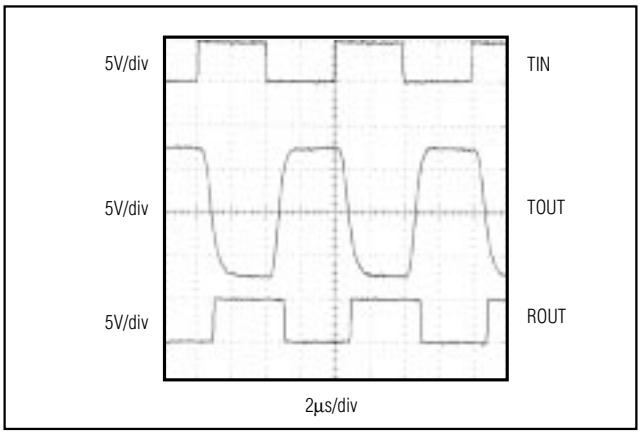

Figure 8. Loopback Test Result at 250kbps

Chip Information

TRANSISTOR COUNT: 157