



# 1.6 $\mu$ A, RS-485/RS-422, Half-Duplex, Differential Transceiver for Battery-Powered Systems

MAX3471

## General Description

The MAX3471 half-duplex transceiver is intended for lithium battery-powered RS-485/RS-422 applications. It draws only 1.6 $\mu$ A (typical) supply current from a 3.6V supply with the receiver enabled and the driver disabled. Its wide 2.5V to 5.5V supply voltage guarantees operation over the lifetime of a lithium battery.

This device features true fail-safe operation that guarantees a logic-high receiver output when the receiver inputs are open or shorted. This means that the receiver output will be a logic high if all transmitters on a terminated bus are disabled (high impedance). The MAX3471 has a 1/8-unit load input resistance. When driver outputs are enabled and pulled above V<sub>CC</sub> or below GND, internal circuitry prevents battery back-charging.

The MAX3471 is available in an 8-pin  $\mu$ MAX package.

## Applications

Remote Meter Reading  
Battery-Powered Differential Communications  
Level Translators

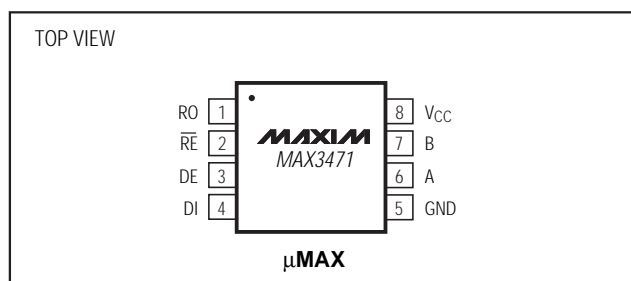
## Features

- ◆ 1.6 $\mu$ A Supply Current with Receiver Enabled
- ◆ +2.5V to +5.5V Single-Supply Operation
- ◆ True Fail-Safe Receiver Input
- ◆ Available in  $\mu$ MAX Package
- ◆ 1/8-Unit-Load Receiver Input
- ◆ -7V to +10V Common-Mode Input Voltage Range

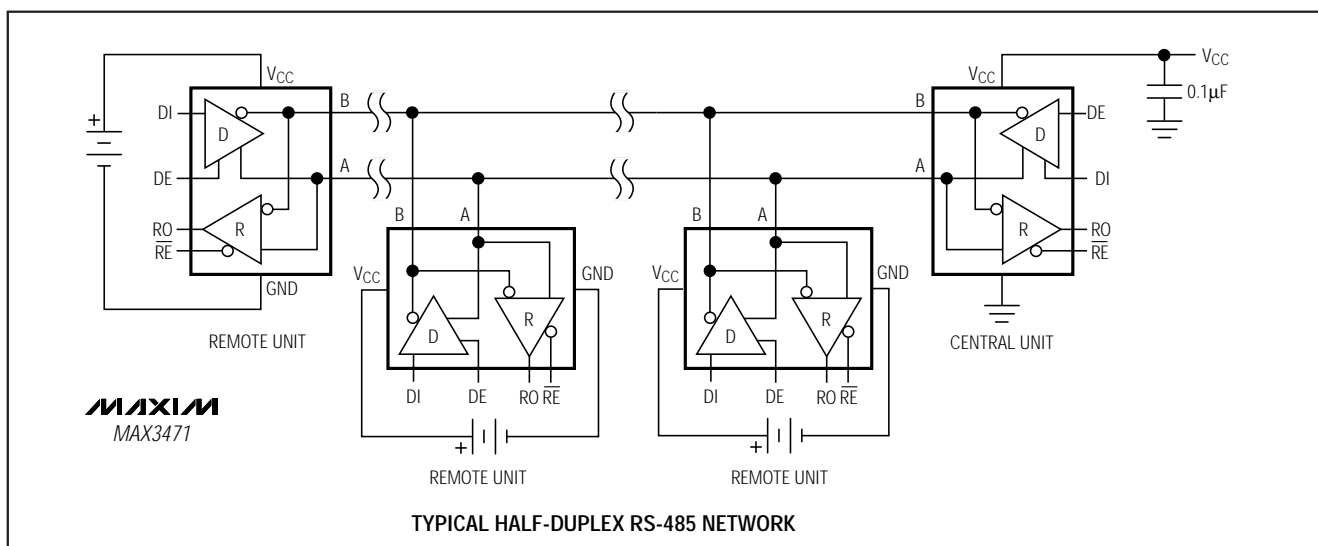
## Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX3471CUA	0°C to +70°C	8 $\mu$ MAX
MAX3471EUA	-40°C to +85°C	8 $\mu$ MAX

## Pin Configuration



## Typical Application Circuit



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## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....7V  
 Control Input Voltage ( $\overline{RE}$ , DE).....-0.3V to ( $V_{CC}$  + 0.3V)  
 Driver Input Voltage (DI).....-0.3V to ( $V_{CC}$  + 0.3V)  
 Driver Output/Receiver Input Voltage (A, B)..... $\pm 10.5$ V  
 Receiver Output Voltage (RO).....-0.3V to ( $V_{CC}$  + 0.3V)  
 Continuous Power Dissipation  
 $\mu$ MAX (derate 4.5mW/ $^{\circ}$ C above +70 $^{\circ}$ C) .....362mW

### Operating Temperature Ranges

MAX3471CUA .....0 $^{\circ}$ C to +70 $^{\circ}$ C  
 MAX3471EUA .....-40 $^{\circ}$ C to +85 $^{\circ}$ C  
 Storage Temperature Range .....-65 $^{\circ}$ C to +160 $^{\circ}$ C  
 Lead Temperature (soldering, 10sec) .....+300 $^{\circ}$ C

**Note 1:** All currents into the device are positive; all currents out of the device are negative. All voltages are referred to device ground unless otherwise noted.

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.

## DC ELECTRICAL CHARACTERISTICS

( $V_{CC}$  = +2.5V to +5.5V,  $T_A$  =  $T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC}$  = +3.6V and  $T_A$  = +25 $^{\circ}$ C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Differential Driver Output (no load)	$V_{OD1}$	Figure 1 (R = open)				$V_{CC}$	V
Differential Driver Output (with load)	$V_{OD2}$	Figure 1	R = 750 $\Omega$ (RS-422)	1.5	3.28		V
			R = 27 $\Omega$ (RS-485)	0.2	0.83		
			R = 27 $\Omega$ (RS-485), $V_{CC}$ = 5V, $T_A$ = +25 $^{\circ}$ C		1.5		
Change in Magnitude of Differential Output Voltage (Note 2)	$\Delta V_{OD}$	Figure 1, R = 750 $\Omega$ or 27 $\Omega$				0.2	V
Driver Common-Mode Output Voltage	$V_{OC}$	Figure 1, R = 750 $\Omega$ or 27 $\Omega$				0.6 x $V_{CC}$	V
Change in Magnitude of Common-Mode Voltage (Note 2)	$\Delta V_{OC}$	Figure 1, R = 750 $\Omega$ or 27 $\Omega$				0.2	V
Input High Voltage	$V_{IH}$	DE, DI, $\overline{RE}$		0.7 x $V_{CC}$			V
Input Low Voltage	$V_{IL}$	DE, DI, $\overline{RE}$		0.3 x $V_{CC}$			V
DI Input Hysteresis	$V_{HYS}$			100			mV
Input Current	$I_{IN1}$	DE, DI, $\overline{RE}$		$\pm 0.001$		$\pm 1$	$\mu$ A
Input Current (A and B), Half Duplex	$I_{IN2}$	DE = GND, $V_{CC}$ = GND or 5.5V	$V_{IN}$ = 10V	0.105			mA
			$V_{IN}$ = -7V	-0.075			
Driver Short-Circuit Output Current (Note 3)	$I_{OSD}$	-7V $\leq V_{OUT} \leq$ 10V	$V_{CC} \leq$ 3.6V	-60		60	mA
			$V_{CC} \leq$ 5.5V	-130		130	
Receiver Differential Threshold Voltage	$V_{TH}$	-7V $\leq V_{CM} \leq$ 10V		-450	-250	-50	mV
Receiver Input Hysteresis	$\Delta V_{TH}$	$V_{CM}$ = 0		32			mV
Receiver Output High Voltage	$V_{OH}$	$I_O$ = -0.8mA, $V_{ID}$ = -50mV		$V_{CC}$ - 0.4			V
Receiver Output Low Voltage	$V_{OL}$	$I_O$ = 2.2mA, $V_{ID}$ = -450mV		0.4			V
Three-State Current at Receiver Output	$I_{OZR}$	0 $\leq V_O \leq V_{CC}$		$\pm 1$			$\mu$ A
Receiver Input Resistance	$R_{IN}$	-7V $\leq V_{CM} \leq$ 10V		96			k $\Omega$

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## DC ELECTRICAL CHARACTERISTICS (continued)

(V<sub>CC</sub> = +2.5V to +5.5V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at V<sub>CC</sub> = +3.6V and T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Receiver Output Short-Circuit Current	I <sub>OSR</sub>	0 ≤ V <sub>RO</sub> ≤ V <sub>CC</sub>	V <sub>CC</sub> ≤ 3.6V	-20		50	mA
			V <sub>CC</sub> ≤ 5.5V	-40		110	
Supply Current	I <sub>CC</sub>	V <sub>CC</sub> ≤ 3.6V, no load, $\overline{RE} = DI = GND$ or V <sub>CC</sub> , V <sub>A</sub> = V <sub>B</sub> = 0	DE = V <sub>CC</sub>		50	60	μA
			DE = GND		1.6	2	
		V <sub>CC</sub> ≤ 5.5V, no load, $\overline{RE} = DI = GND$ or V <sub>CC</sub> , V <sub>A</sub> = V <sub>B</sub> = 0	DE = V <sub>CC</sub>		83	100	
			DE = GND		2.8	4	

## SWITCHING CHARACTERISTICS

(V<sub>CC</sub> = +2.5V to +5.5V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at V<sub>CC</sub> = +3.6V and T<sub>A</sub> = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Driver Input to Output Propagation Delay	t <sub>DPLH</sub> , t <sub>DPHL</sub>	Figures 3 and 5, R <sub>DIFF</sub> = 1.5kΩ, C <sub>L1</sub> = C <sub>L2</sub> = 100pF		1.40	2.00	μs
Driver Output Skew (t <sub>DPLH</sub> - t <sub>DPHL</sub> )	t <sub>DSKEW</sub>	Figures 3 and 5, R <sub>DIFF</sub> = 1.5kΩ, C <sub>L1</sub> = C <sub>L2</sub> = 100pF		0.025		μs
Driver Rise or Fall Time	t <sub>DR</sub> , t <sub>DF</sub>	Figures 3 and 5, R <sub>DIFF</sub> = 1.5kΩ, C <sub>L1</sub> = C <sub>L2</sub> = 100pF	0.75	1.34	1.75	μs
Driver Enable Time to Output High	t <sub>DZH</sub>	Figures 4 and 6, C <sub>L</sub> = 100pF, S2 closed, S1 open		1.5	6.00	μs
Driver Enable Time to Output Low	t <sub>DZL</sub>	Figures 4 and 6, C <sub>L</sub> = 100pF, S1 closed, S2 open		0.86	4.00	μs
Driver Disable Time from Low	t <sub>DLZ</sub>	Figures 4 and 6, C <sub>L</sub> = 15pF, S1 closed, S2 open		0.4	1.5	μs
Driver Disable Time from High	t <sub>DHZ</sub>	Figures 4 and 6, C <sub>L</sub> = 15pF, S2 closed, S1 open		0.6	1.5	μs
Receiver Input to Output Propagation Delay	t <sub>RPLH</sub>	Figures 7 and 9, C <sub>L</sub> = 15pF,  V <sub>ID</sub>   = 2V		5.2	12	μs
	t <sub>RPHL</sub>			6.4	12	
Differential Receiver Skew (t <sub>RPLH</sub> - t <sub>RPHL</sub> )	t <sub>RSKEW</sub>	Figures 7 and 9,  V <sub>ID</sub>   = 2V		1.2		μs
Data Rate	f <sub>MAX</sub>	Figure 9, C <sub>L</sub> = 100pF	64			kbps
Receiver Enable Time to Output Low	t <sub>RZL</sub>	Figures 2 and 8, C <sub>L</sub> = 15pF, S1 closed, S2 open		70	500	ns
Receiver Enable Time to Output High	t <sub>RZH</sub>	Figures 2 and 8, C <sub>L</sub> = 15pF, S2 closed, S1 open		85	500	ns
Receiver Disable Time from Low	t <sub>RLZ</sub>	Figures 2 and 8, C <sub>L</sub> = 15pF, S1 closed, S2 open		50	200	ns
Receiver Disable Time from High	t <sub>RHZ</sub>	Figures 2 and 8, C <sub>L</sub> = 15pF, S2 closed, S1 open		35	200	ns

**Note 1:** All currents into the device are positive; all currents out of the device are negative. All voltages are referred to device ground unless otherwise noted.

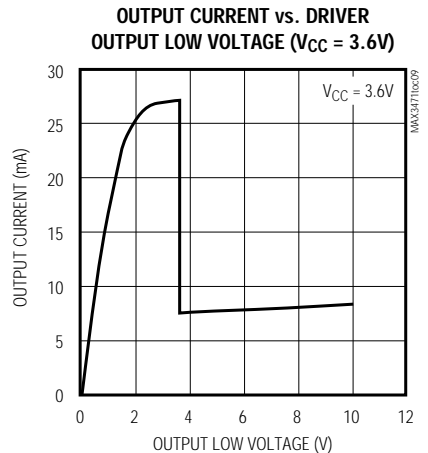
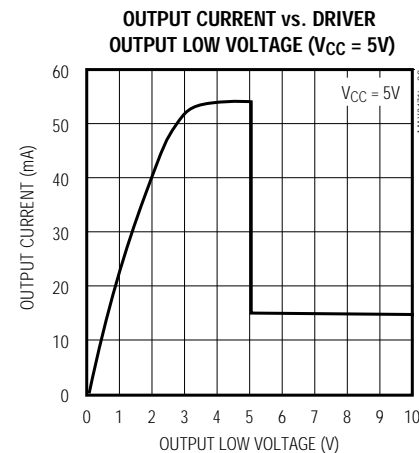
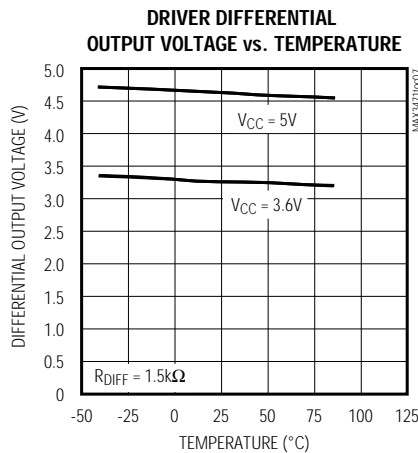
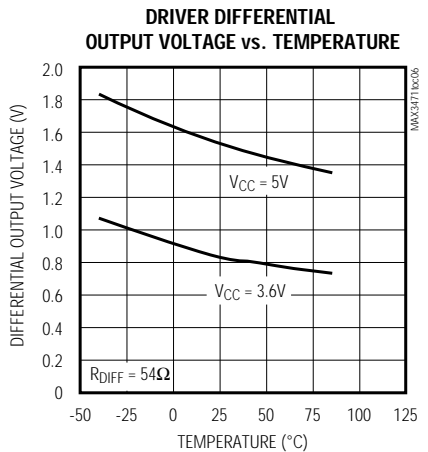
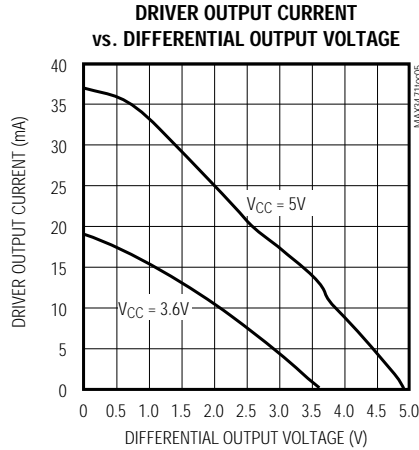
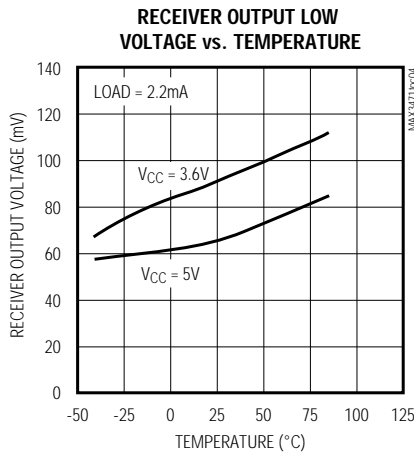
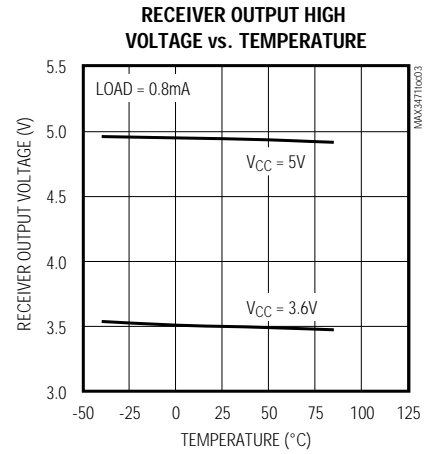
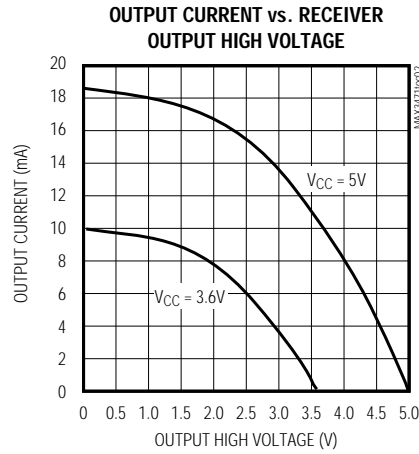
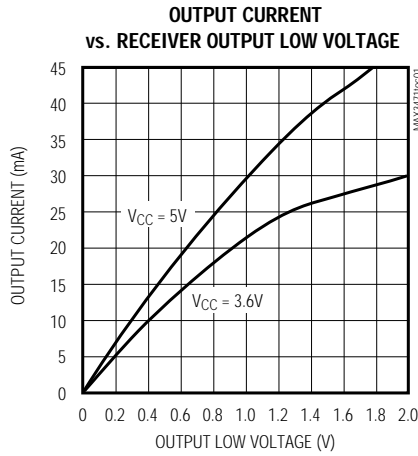
**Note 2:** ΔV<sub>OD</sub> and ΔV<sub>OC</sub> are the changes in magnitude of V<sub>OD</sub> and V<sub>OC</sub>, respectively, when the DI input changes state.

**Note 3:** Maximum and minimum current levels apply to peak current just prior to foldback-current limiting.

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## Typical Operating Characteristics

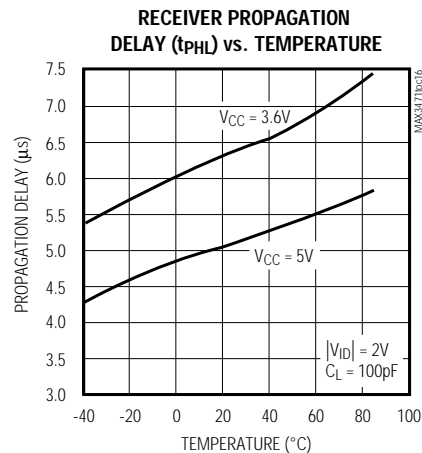
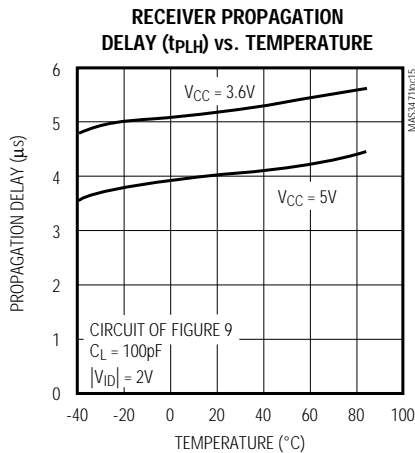
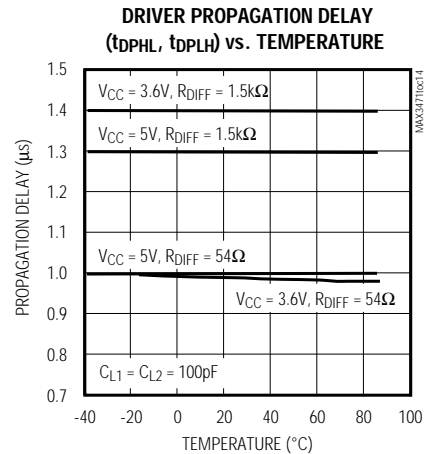
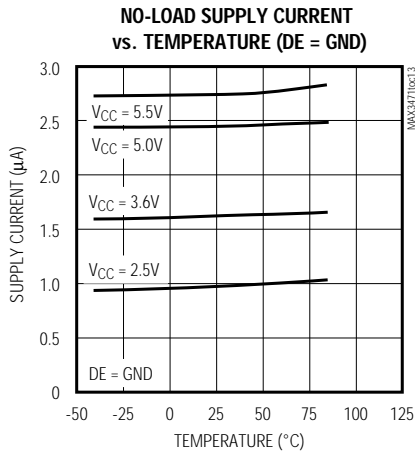
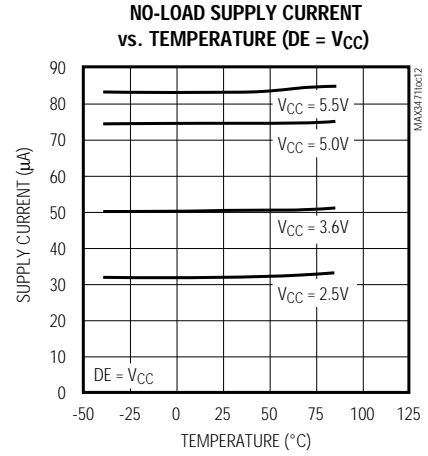
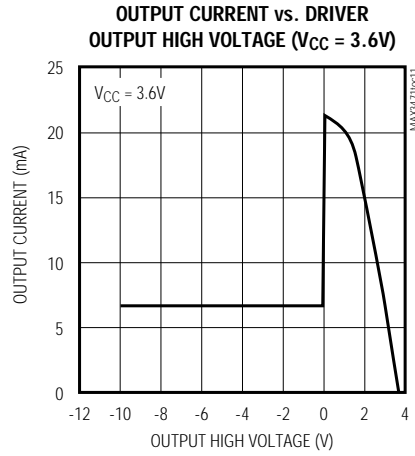
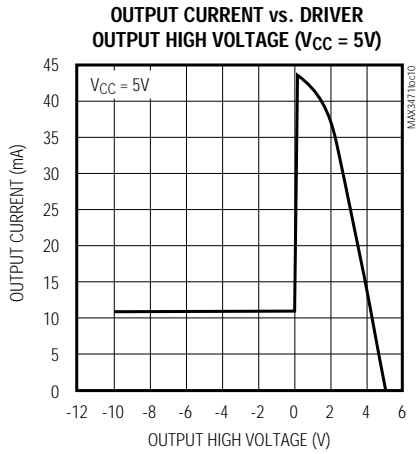
( $V_{CC} = +3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 1.6 $\mu$ A, RS-485/RS-422, Half-Duplex, Differential Transceiver for Battery-Powered Systems

## Typical Operating Characteristics (continued)

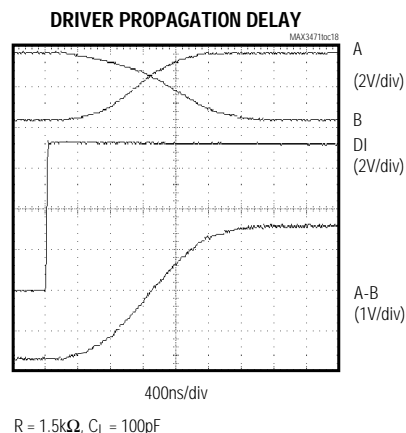
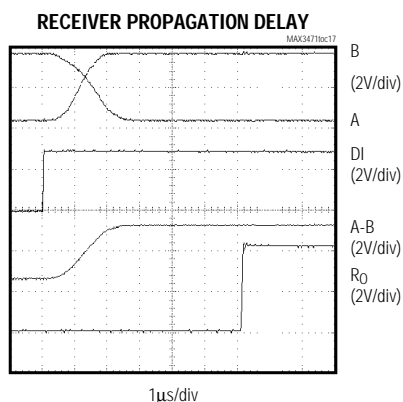
( $V_{CC} = +3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 1.6 $\mu$ A, RS-485/RS-422, Half-Duplex, Differential Transceiver for Battery-Powered Systems

## Typical Operating Characteristics (continued)

( $V_{CC} = +3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

PIN	NAME	FUNCTION
1	RO	Receiver Output. When $\overline{RE}$ is low, if $A - B \geq -50mV$ , RO will be high; if $A - B \leq -450mV$ , RO will be low.
2	$\overline{RE}$	Receiver Output Enable. Drive $\overline{RE}$ low to enable RO; RO is high impedance when $\overline{RE}$ is high.
3	DE	Driver Output Enable. Drive DE high to enable the driver outputs. These outputs are high impedance when DE is low.
4	DI	Driver Input. With DE high, a low on DI forces the noninverting output low and the inverting output high. Similarly, a high on DI forces the noninverting output high and the inverting output low.
5	GND	Ground
6	A	Noninverting Driver Output and Noninverting Receiver Input
7	B	Inverting Driver Output and Inverting Receiver Input
8	VCC	Positive Supply: $+2.5V \leq V_{CC} \leq +5.5V$

## Detailed Description

The MAX3471 half-duplex transceiver consumes only 1.6 $\mu$ A from a single +3.6V supply. Its wide 2.5V to 5.5V supply voltage guarantees operation over the lifetime of a lithium battery. This device contains one driver and one receiver. Its true fail-safe receiver input guarantees a logic-high receiver output when the receiver inputs are open or shorted, or when they are connected to a terminated transmission line with all drivers disabled. Reduced-slew-rate drivers minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free data transmission up to 64kbps.

### Receiver Input Filtering

The MAX3471 receiver operates at up to 64kbps and incorporates input filtering in addition to input hysteresis.

This filtering enhances noise immunity when differential signals have very slow rise and fall times.

The MAX3471 guarantees a logic-high receiver output when the receiver inputs are shorted or open, or when they are connected to a terminated transmission line with all drivers disabled. This is accomplished by setting the receiver threshold between -50mV and -450mV. If the differential receiver input voltage (A-B) is greater than or equal to -50mV, RO is a logic high. If A-B is less than or equal to -450mV, RO is a logic low. In the case of a terminated bus with all transmitters disabled, the receiver's differential input voltage is pulled to 0V by the termination. With the MAX3471's receiver thresholds, this results in a logic high with a 50mV minimum noise margin.

# 1.6 $\mu$ A, RS-485/RS-422, Half-Duplex, Differential Transceiver for Battery-Powered Systems

**Table 1. Transmitting**

INPUTS			OUTPUTS	
$\overline{\text{RE}}$	DE	DI	B	A
X	1	1	0	1
X	1	0	1	0
0	0	X	Z <sub>D</sub>	Z <sub>D</sub>
1	0	X	Z <sub>D</sub>	Z <sub>D</sub>

Z<sub>D</sub> = Driver output disabled

**Table 2. Receiving**

INPUTS			OUTPUT
$\overline{\text{RE}}$	DE	A-B	RO
0	0	$\geq -0.05\text{V}$	1
0	0	$\leq -0.45\text{V}$	0
0	0	Open/Shorted	1
1	0	X	Z

X = Don't care

Z = Receiver output high impedance

## Applications Information

### Transceivers on the Bus

The MAX3471 is optimized for the unterminated bus normally used in slow, low-power systems. With a +2.5V supply, the part is guaranteed to drive up to eight standard loads (for example, 64 other MAX3471s or 56 MAX3471s plus one standard load). Drive capability increases significantly with supply. For example, with a +5V supply, the MAX3471 typically meets the RS-485 driver output specifications (1.5V with 54 $\Omega$  differential termination). See the *Typical Operating Characteristics*.

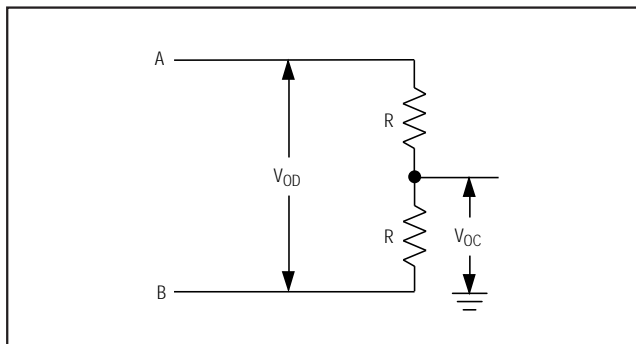


Figure 1. Driver DC Test Load

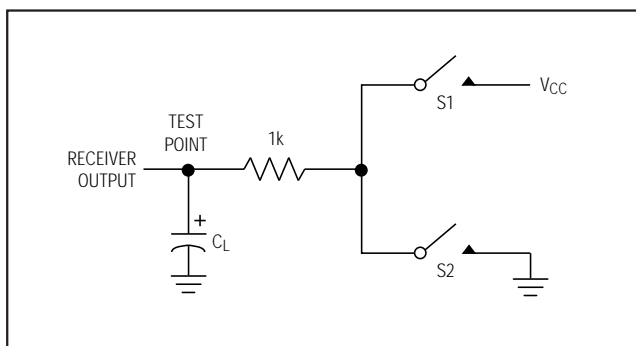


Figure 2. Receiver Enable/Disable Timing Test Load

### Reduced EMI and Reflections

The MAX3471 is slew-rate limited, minimizing EMI and reducing reflections caused by improperly terminated cables. In general, the rise time of a transmitter directly relates to the length of an unterminated stub, which can be driven with only minor waveform reflections. The following equation expresses this relationship conservatively:

$$\text{Length} = t_{\text{RISE}} / (10 \times 1.5\text{ns/foot})$$

where  $t_{\text{RISE}}$  is the transmitter's rise time.

For example, the MAX3471's rise time is typically 1.3 $\mu$ s, which results in excellent waveforms with a stub length up to 82 feet. In general, systems operate well with longer unterminated stubs, even with severe reflections, if the waveform settles out before the UART samples them.

### Driver Output Protection

Excessive output current and power dissipation caused by faults or bus contention are prevented by foldback current limiting. A foldback current limit on the output stage provides immediate protection against short circuits over the whole common-mode voltage range (see *Typical Operating Characteristics*).

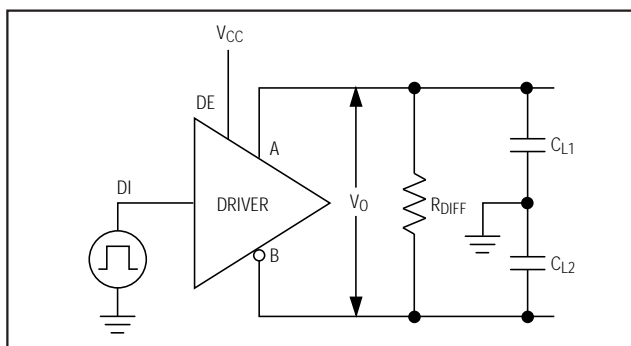


Figure 3. Driver Test Circuit

# 1.6 $\mu$ A, RS-485/RS-422, Half-Duplex, Differential Transceiver for Battery-Powered Systems

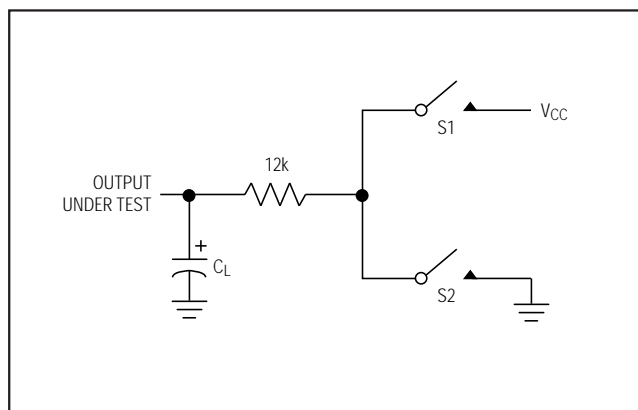


Figure 4. Driver Enable/Disable Timing Test Load

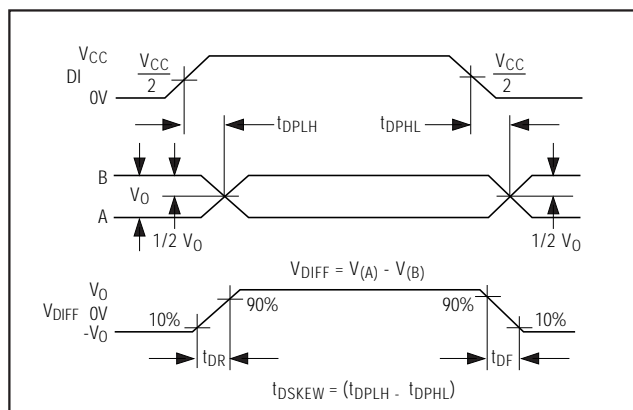


Figure 5. Driver Differential Propagation Delay and Rise/Fall Times

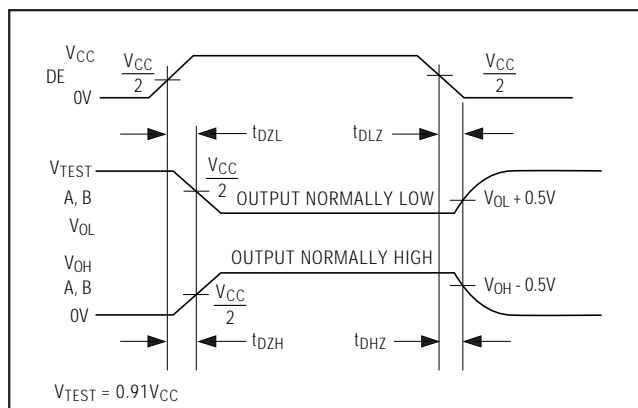


Figure 6. Driver Enable and Disable Times

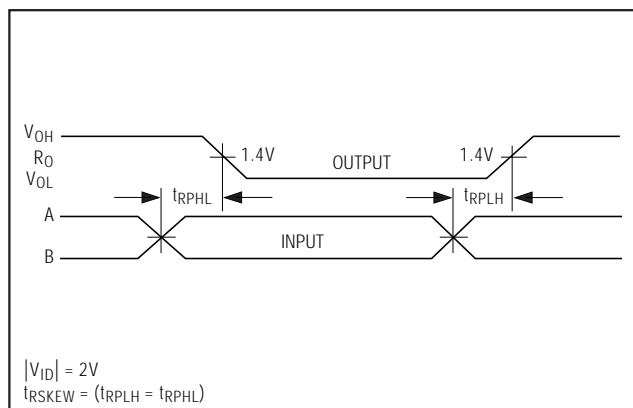


Figure 7. Receiver Propagation Delay

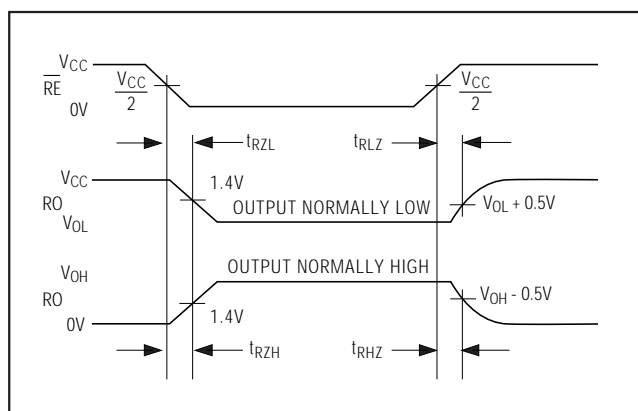


Figure 8. Receiver Enable and Disable Times

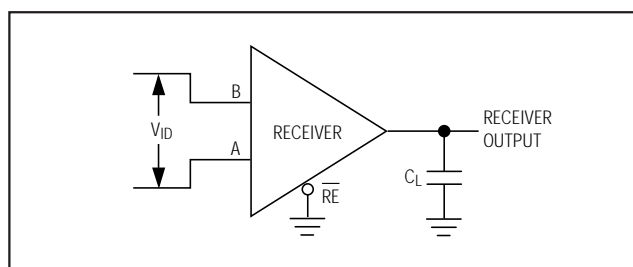


Figure 9. Receiver Propagation Delay and Maximum Data-Rate Test Circuit

## Chip Information

TRANSISTOR COUNT: 351

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