



# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## General Description

The MAX3370/MAX3371 logic-level translators are ideal for applications interfacing low-voltage devices to other logic levels. Externally applied voltages set the logic levels of the MAX3370/MAX3371. The devices accept  $V_{CC}$  from +2.5V to +5.5V and  $V_L$  from +1.6V to +5.5V, allowing data transfer between low-voltage ASICs and higher voltage devices. The MAX3371 features a shut-down mode that reduces supply current to  $< 1\mu A$  and puts the I/O pins in a high-impedance state.

The MAX3370/MAX3371 are bidirectional level shifters, allowing data transfer from the  $V_{CC}$  side to the  $V_L$  side and from the  $V_L$  side to the  $V_{CC}$  side. Both devices operate at speeds up to 2Mbps with an active driver and up to 500kbps with an open-drain driver.

The MAX3370/MAX3371 are available in space-saving  $\mu$ DFN (1mm x 1.5mm) and SC70 packages.

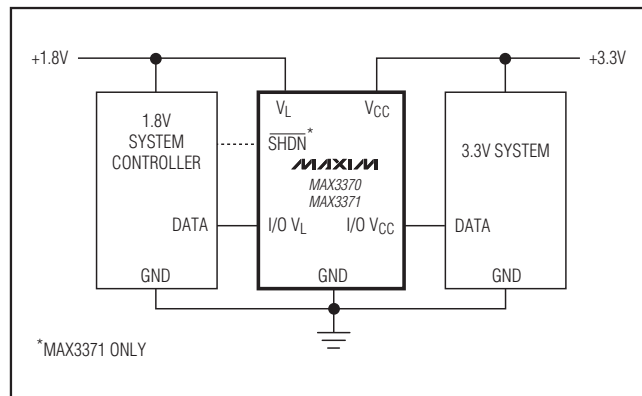
## Applications

Cell Phone Cradles  
Cell Phone Hands-Free Kits  
Portable POS Systems  
Portable Communication Devices  
Smart Card Readers  
SPI™, MICROWIRE™, and I<sup>2</sup>C Level Translation  
Low-Voltage ASIC Level Translation  
RS-232-Compatible Translation

SPI is a trademark of Motorola, Inc.

MICROWIRE is a trademark of National Semiconductor Corp.

## Typical Operating Circuit



†MAX3370/MAX3371 covered by U.S. Patent number 5,894,240.

## Features

- ◆ Allow Bidirectional Level Translation
- ◆ Miniature  $\mu$ DFN (1mm x 1.5mm) and SC70 Packages
- ◆ Operational Down to 1.6V
- ◆ Low Quiescent Current ( $< 100\mu A$ )
- ◆ Ultra-Low ( $< 1\mu A$ ) Shutdown Supply Current (MAX3371)
- ◆ Three-State Outputs in Shutdown (MAX3371)
- ◆ 2Mbps (10pF Load) Push-Pull Driving
- ◆ 1Mbps (50pF Load) Push-Pull Driving
- ◆ 500kbps (30pF Load) Open-Drain Driving

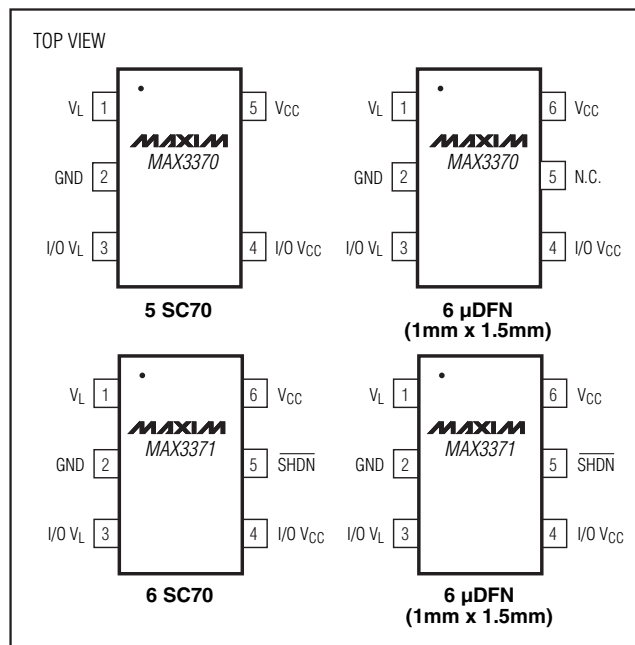
## Ordering Information

PART*	PIN-PACKAGE	SHDN	TOP MARK
MAX3370EXK+T	5 SC70	NO	ABV
MAX3370ELT+T	6 $\mu$ DFN	NO	KX
MAX3371ELT+T	6 $\mu$ DFN	YES	KY
MAX3371EXT+T	6 SC70	YES	AAO

\*All devices are specified over the  $-40^{\circ}C$  to  $+85^{\circ}C$  operating temperature range.

+Denotes lead(Pb)-free/RoHS-compliant package.

## Pin Configurations



MAX3370/MAX3371

# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## ABSOLUTE MAXIMUM RATINGS

V<sub>CC</sub> to GND .....-0.3V to +7V  
 SHDN to GND .....-0.3V to (V<sub>L</sub> + 0.3V)  
 I/O V<sub>L</sub> to GND .....-0.3V to (V<sub>L</sub> + 0.3V)  
 V<sub>L</sub>, I/O V<sub>CC</sub> to GND .....-0.3V to (V<sub>CC</sub> + 0.3V)  
 Short-Circuit Duration: I/O V<sub>L</sub>, I/O V<sub>CC</sub> to GND .....Continuous

Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
 SC70 (derate 3.1mW/°C above +70°C) .....245mW  
 6-Pin  $\mu$ DFN (derate 2.1mW/°C above +70°C) .....168mW  
 Operating Temperature Range .....-40°C to +85°C  
 Storage Temperature Range .....-65°C to +150°C  
 Lead Temperature (soldering, 10s) .....+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<sub>CC</sub> = +2.5V to +5.5V, V<sub>L</sub> = +1.6V to +5.5V (Note 1), GND = 0; I/O V<sub>L</sub>, I/O V<sub>CC</sub> unconnected; T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>POWER SUPPLIES</b>						
V <sub>L</sub> Supply Range	V <sub>L</sub>	(Note 1)	1.6		5.5	V
V <sub>CC</sub> Supply Range	V <sub>CC</sub>		2.5		5.5	V
Supply Current from V <sub>CC</sub>	I <sub>QVCC</sub>			70	100	$\mu$ A
Supply Current from V <sub>L</sub>	I <sub>QVL</sub>			5	100	$\mu$ A
V <sub>CC</sub> Shutdown Supply Current		SHDN = GND, T <sub>A</sub> = +25°C, MAX3371		0.03	1	$\mu$ A
V <sub>L</sub> Shutdown Supply Current		SHDN = GND, T <sub>A</sub> = +25°C, MAX3371		0.03	1	$\mu$ A
Three-State Output Leakage Current		I/O V <sub>L</sub> , I/O V <sub>CC</sub> ; SHDN = GND, T <sub>A</sub> = +25°C, MAX3371		0.02	1	$\mu$ A
<b>LOGIC LEVEL THRESHOLDS</b>						
I/O V <sub>L</sub> Input-Voltage High Threshold	V <sub>IHL</sub>				V <sub>L</sub> - 0.2	V
I/O V <sub>L</sub> Input-Voltage Low Threshold	V <sub>ILL</sub>		0.15			V
I/O V <sub>CC</sub> Input-Voltage High Threshold	V <sub>IHC</sub>				V <sub>CC</sub> - 0.4	V
I/O V <sub>CC</sub> Input-Voltage Low Threshold	V <sub>ILC</sub>		0.2			V
I/O V <sub>L</sub> Output-Voltage High	V <sub>OHL</sub>	I/O V <sub>L</sub> sink current = 20 $\mu$ A, I/O V <sub>CC</sub> $\geq$ V <sub>CC</sub> - 0.4V (Note 3)	2/3 $\times$ V <sub>L</sub>			V
I/O V <sub>L</sub> Output-Voltage Low	V <sub>OLL</sub>	I/O V <sub>L</sub> sink current = 1mA, I/O V <sub>CC</sub> $\leq$ 0.2V (Note 3)		0.4		V
I/O V <sub>CC</sub> Output-Voltage High	V <sub>OHC</sub>	I/O V <sub>CC</sub> source current = 20 $\mu$ A, I/O V <sub>L</sub> $\geq$ V <sub>L</sub> - 0.2V (Note 3)	2/3 $\times$ V <sub>CC</sub>			V
I/O V <sub>CC</sub> Output-Voltage Low	V <sub>OLC</sub>	I/O V <sub>CC</sub> sink current = 1mA, I/O V <sub>L</sub> $\leq$ 0.15V (Note 3)		0.4		V
SHDN Input-Voltage High	V <sub>IH-SHDN</sub>		2/3 $\times$ V <sub>L</sub>			V
SHDN Input-Voltage Low	V <sub>IL-SHDN</sub>	V <sub>L</sub> $\geq$ +1.8V		0.4		V
		V <sub>L</sub> $\geq$ +1.6V		0.2		

# 1μA, 2Mbps, Low-Voltage Level Translators in SC70 and μDFN

## ELECTRICAL CHARACTERISTICS (continued)

(V<sub>CC</sub> = +2.5V to +5.5V, V<sub>L</sub> = +1.6V to +5.5V (Note 1), GND = 0; I/O V<sub>L</sub>, I/O V<sub>CC</sub> unconnected; T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>TIMING CHARACTERISTICS</b> (R <sub>LOAD</sub> = 1MΩ, V <sub>CC</sub> = +2.5V, V <sub>L</sub> = +1.6V, I/O test signal rail-to-rail, unless otherwise noted, Figure 1) (Note 3)						
I/O V <sub>CC</sub> Rise Time (Note 4)	trVCC	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			100	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			200	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			400	
I/O V <sub>CC</sub> Fall Time (Note 4)	tfVCC	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			50	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			200	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			400	
I/O V <sub>L</sub> Rise Time (Note 4)	trVL	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			100	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			200	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			400	
I/O V <sub>L</sub> Fall Time (Note 4)	tfVL	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			50	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			200	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			400	
HIGH-to-LOW Transition Propagation Delay (Driving I/O V <sub>L</sub> )	tPD-VCC-HL	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			50	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			200	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			400	
LOW-to-HIGH Transition Propagation Delay (Driving I/O V <sub>L</sub> )	tPD-VCC-LH	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			200	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			400	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			800	
HIGH-to-LOW Transition Propagation Delay (Driving I/O V <sub>CC</sub> )	tPD-VL-HL	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			50	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			200	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			400	
LOW-to-HIGH Transition Propagation Delay (Driving I/O V <sub>CC</sub> )	tPD-VL-LH	C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 5)			200	ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps			400	
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive			800	
HIGH-to-LOW Transition Propagation Delay Device-to-Device Skew (Driving I/O V <sub>L</sub> )		C <sub>LOAD</sub> = 10pF, data rate = 2Mbps (Note 3)		2		ns
		C <sub>LOAD</sub> = 50pF, data rate = 1Mbps		4		
		C <sub>LOAD</sub> = 30pF, data rate = 500kbps, open-drain drive		5		

MAX3370/MAX3371

# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC}$  = +2.5V to +5.5V,  $V_L$  = +1.6V to +5.5V (Note 1), GND = 0; I/O  $V_L$ , I/O  $V_{CC}$  unconnected;  $T_A$  = -40°C to +85°C, unless otherwise noted. Typical values are at  $T_A$  = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
LOW-to-HIGH Transition Propagation Delay Device-to-Device Skew (Driving I/O $V_L$ )		$C_{LOAD}$ = 10pF, data rate = 2Mbps (Note 3)		5		ns
		$C_{LOAD}$ = 50pF, data rate = 1Mbps		8		
		$C_{LOAD}$ = 30pF, data rate = 500kbps, open-drain drive		80		
HIGH-to-LOW Transition Propagation Delay Device-to-Device Skew (Driving I/O $V_{CC}$ )		$C_{LOAD}$ = 10pF, data rate = 2Mbps (Note 3)		2		ns
		$C_{LOAD}$ = 50pF, data rate = 1Mbps		4		
		$C_{LOAD}$ = 30pF, data rate = 500kbps, open-drain drive		5		
LOW-to-HIGH Transition Propagation Delay Device-to-Device Skew (Driving I/O $V_{CC}$ )		$C_{LOAD}$ = 10pF, data rate = 2Mbps (Note 3)		7		ns
		$C_{LOAD}$ = 50pF, data rate = 1Mbps		8		
		$C_{LOAD}$ = 30pF, data rate = 500kbps, open-drain drive		50		
Maximum Data Rate		$C_{LOAD}$ = 10pF (Note 5)	2	3		Mbps
		$C_{LOAD}$ = 50pF	1	2		
		$C_{LOAD}$ = 30pF, open-drain drive	0.5	1		

**Note 1:**  $V_L$  must always be less than or equal to  $V_{CC}$ .

**Note 2:** All units are 100% production tested at  $T_A$  = +25°C. Limits over the operating temperature range are guaranteed by design and not production tested.

**Note 3:** Tested only at worst case:  $V_{CC}$  = +2.5V,  $V_L$  = +1.6V.

**Note 4:** 10% to 90%.

**Note 5:** Guaranteed by correlation to  $C_{LOAD}$  = 50pF.

# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

MAX3370/MAX3371

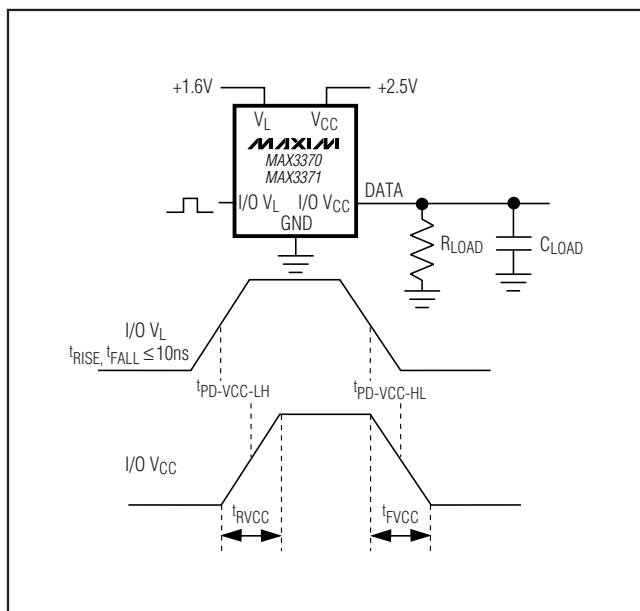


Figure 1a. Rail-to-Rail Driving I/O V<sub>L</sub>

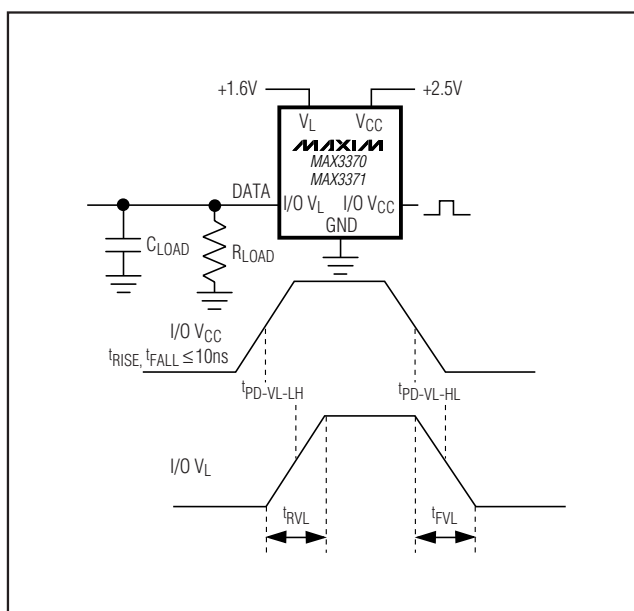


Figure 1b. Rail-to-Rail Driving I/O V<sub>CC</sub>

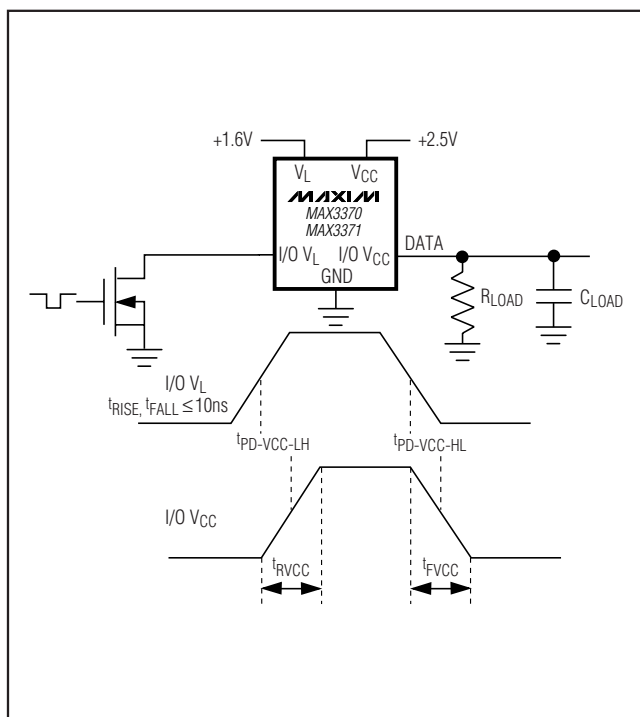


Figure 1c. Open-Drain Driving I/O V<sub>L</sub>

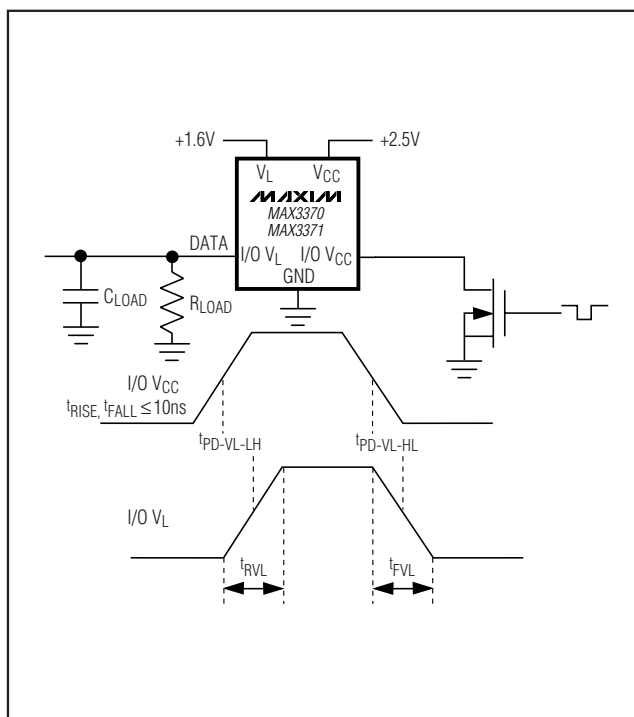
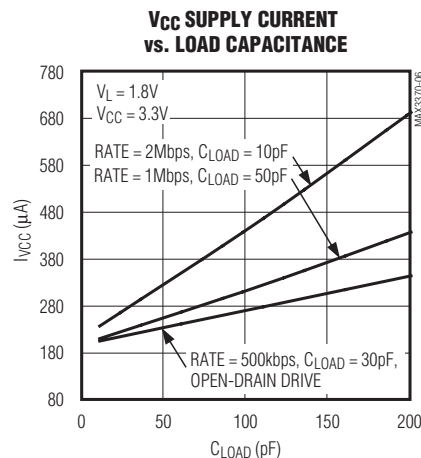
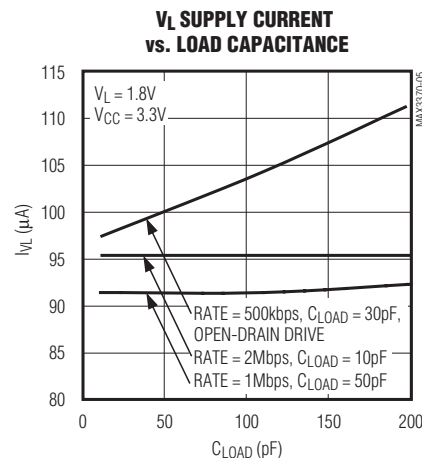
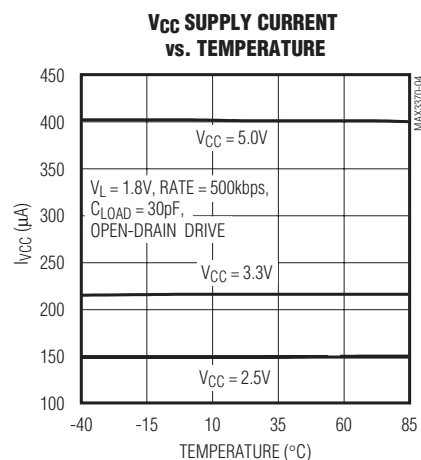
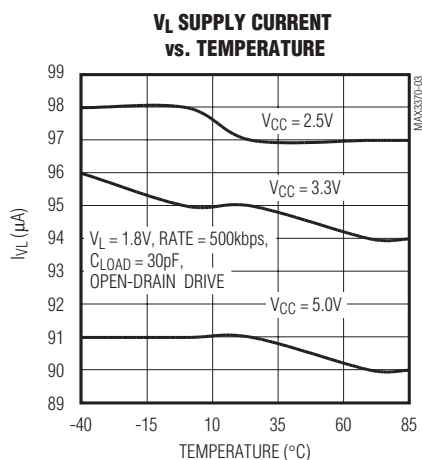
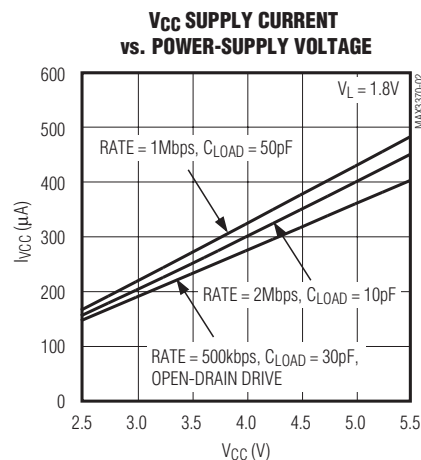
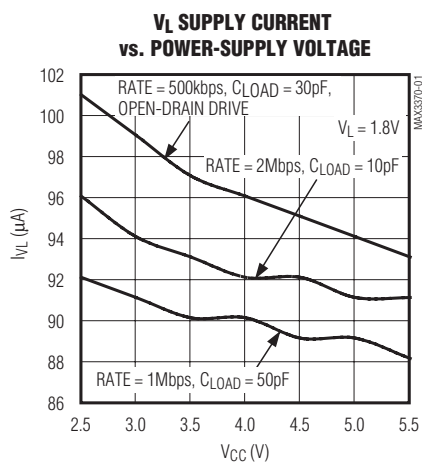


Figure 1d. Open-Drain Driving I/O V<sub>CC</sub>

# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## Typical Operating Characteristics

(Driving I/O  $V_L$  rail-to-rail,  $R_L = 1M\Omega$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

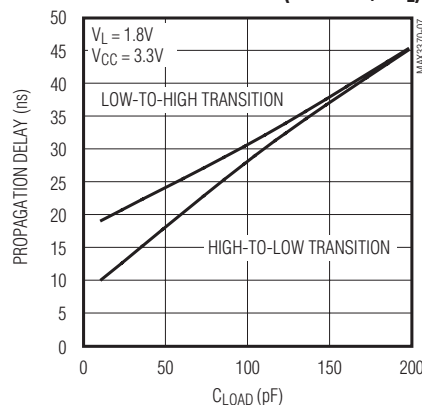


# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

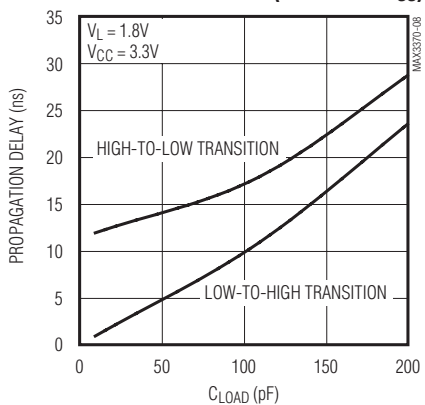
## Typical Operating Characteristics (continued)

(Driving I/O  $V_L$  rail-to-rail,  $R_L = 1M\Omega$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

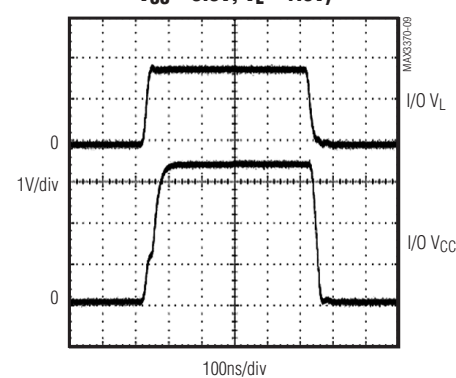
**PROPAGATION DELAY vs. LOAD CAPACITANCE (DRIVING I/O  $V_L$ )**



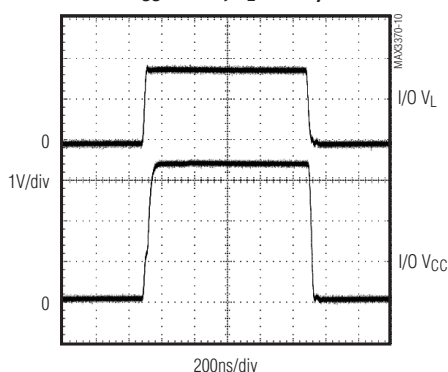
**PROPAGATION DELAY vs. LOAD CAPACITANCE (DRIVING I/O  $V_{CC}$ )**



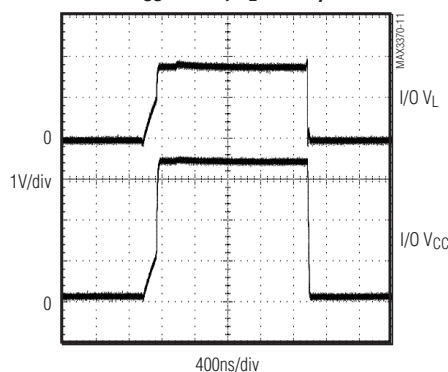
**RAIL-TO-RAIL DRIVING (RATE = 2Mbps,  $C_{LOAD} = 10\text{pF}$ ,  $V_{CC} = 3.3\text{V}$ ,  $V_L = 1.8\text{V}$ )**



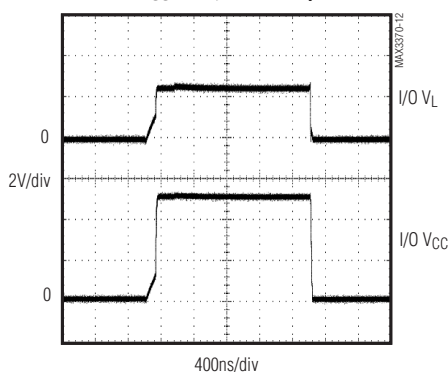
**RAIL-TO-RAIL DRIVING (RATE = 1Mbps,  $C_{LOAD} = 50\text{pF}$ ,  $V_{CC} = 3.3\text{V}$ ,  $V_L = 1.8\text{V}$ )**



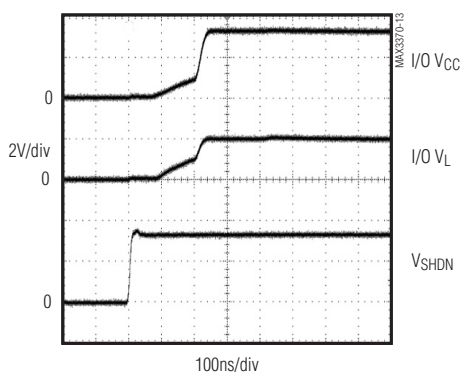
**OPEN-DRAIN DRIVING (RATE = 500kbps,  $C_{LOAD} = 30\text{pF}$ ,  $V_{CC} = 3.3\text{V}$ ,  $V_L = 1.8\text{V}$ )**



**OPEN-DRAIN DRIVING (RATE = 500kbps,  $C_{LOAD} = 30\text{pF}$ ,  $V_{CC} = 5\text{V}$ ,  $V_L = 2.5\text{V}$ )**



**MAX3371 EXITING SHUTDOWN**



MAX3370/MAX3371

# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## Pin Description

PIN			NAME	FUNCTION
MAX3370		MAX3371 (SC70-6 AND μDFN-6)		
(SC70-5)	(μDFN-6)			
1	1	1	V <sub>L</sub>	Logic Supply Voltage
2	2	2	GND	Ground
3	3	3	I/O V <sub>L</sub>	Input/Output Referred to V <sub>L</sub>
4	4	4	I/O V <sub>CC</sub>	Input/Output Referred to V <sub>CC</sub>
5	6	6	V <sub>CC</sub>	Power-Supply Voltage
—	—	5	$\overline{\text{SHDN}}$	Shutdown. A high turns on the device. A low shuts down the device. I/O V <sub>CC</sub> and I/O V <sub>L</sub> are high impedance in shutdown.
—	5	—	N.C.	No Connection

## Detailed Description

The MAX3370/MAX3371 provide the necessary level translation to allow data transfer in a multivoltage system. These devices transmit data between an I/O pin referenced to V<sub>CC</sub> and an I/O pin referenced to V<sub>L</sub>. The V<sub>CC</sub> supply voltage range is from +2.5V to +5.5V, and the V<sub>L</sub> supply voltage range is between +1.6V and +5.5V. The MAX3371 features a shutdown mode in which I/O V<sub>CC</sub> and I/O V<sub>L</sub> are placed in a high-impedance state and supply current drops to 1 $\mu$ A.

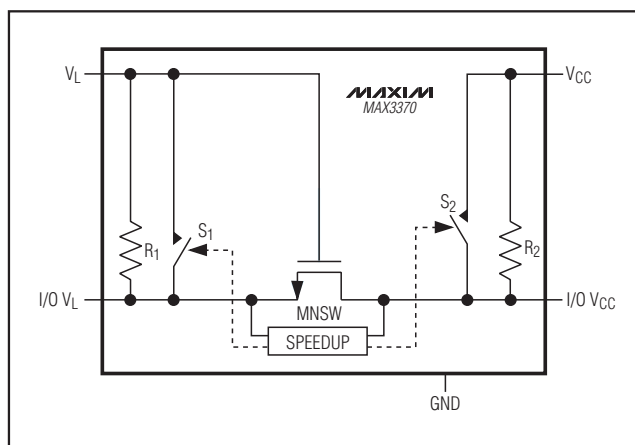
The MAX3370/MAX3371 are bidirectional level shifters allowing data transfer from the V<sub>CC</sub> side to the V<sub>L</sub> side, and from the V<sub>L</sub> side to the V<sub>CC</sub> side. Both devices operate at speeds up to 2Mbps with an active driver and up to 500kbps with an open-drain driver.

### Level Translation

The MAX3370/MAX3371 provide bidirectional level translation between I/O pins referred to V<sub>CC</sub> and V<sub>L</sub>. I/O V<sub>CC</sub> and I/O V<sub>L</sub> are internally pulled up to their respective power-supply rails through 10k $\Omega$  resistors. V<sub>CC</sub> must be between +2.5V and +5.5V, and V<sub>L</sub> must be between +1.6V and +5.5V. For proper operation, V<sub>L</sub> can not exceed V<sub>CC</sub>.

The MAX3370/MAX3371 can operate at data rates up to 2Mbps when driven by an active (push-pull) driver with a 10pF load, 1Mbps when driven by an active driver with a 50pF load, or 500kbps when driven by an open-drain driver with a 30pF load. The internal pullups allow these devices to be driven by open-drain drivers.

## Functional Diagram



### MAX3371 Shutdown Mode

The MAX3371 enters a low-power shutdown mode when  $\overline{\text{SHDN}}$  is driven low. Connect  $\overline{\text{SHDN}}$  to V<sub>L</sub> or drive high for normal operation. Activating shutdown mode disconnects the internal 10k $\Omega$  pullup resistors on I/O V<sub>CC</sub> and I/O V<sub>L</sub>. As a result, the supply current decreases to < 1 $\mu$ A, and the I/O lines are high impedance. The high impedance I/O lines in shutdown allow use in a multidrop network. When in shutdown, I/O V<sub>L</sub> can be driven to V<sub>L</sub> and I/O V<sub>CC</sub> can be driven to V<sub>CC</sub>.



# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## Speed-Up

The speed-up circuit is a one-shot generator that helps the rise time of the output waveform in the low-to-high transition. When triggered, switches  $S_1$  and  $S_2$  turn on for 320ns to pull up I/O  $V_L$  and I/O  $V_{CC}$ . This greatly reduces the rise time and propagation delay for the low-to-high transition as well as improves the duty cycle (closer to 50% for an ideal square-wave input). See the scope plots in the *Typical Operating Characteristics* for the speed-up circuitry in operation.

## Applications Information

### Power-Supply Decoupling

To reduce ripple and the chance of transmitting incorrect data, decouple  $V_{CC}$  and  $V_L$  to ground with a 0.1 $\mu$ F capacitor as close to the device as possible.

### I<sup>2</sup>C Level Translation

The MAX3370/MAX3371 are ideal for level translation between a low-voltage ASIC and an I<sup>2</sup>C device. The devices' bidirectional natures allow their use in the data line of I<sup>2</sup>C communications. A typical application is interfacing a low-voltage microprocessor to a 3V or 5V D/A converter, such as the MAX517.

The I/O lines on the MAX3370/MAX3371 are bidirectional, can be level-shifted up to +5.5V, and contain internal 10k $\Omega$  pullup resistors to allow open-drain driving (see the *Typical Operating Circuit*).

### Push-Pull vs. Open-Drain Driving

The MAX3370/MAX3371 I/O pins can be driven by a push-pull or open-drain device. When using a push-pull driver, the MAX3370/MAX3371 operate up to 2Mbps with a 10pF load or 1Mbps with a 50pF load. The internal pullup resistors on the I/O pins allow use with open-drain devices. The MAX3370/MAX3371 operate up to 500kbps with a 30pF load when driven by an open-drain device.

Data rates higher than those listed in the *Electrical Characteristics* table can be achieved. The maximum data rate is limited to 3Mbps by the speed-up circuitry.

### Unidirectional vs. Bidirectional Level Translator

The MAX3370/MAX3371 may also be used to translate unidirectional signals without signal inversion. The devices provide the smallest solution (SC70 package) for unidirectional level translation without inversion.

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
5 SC70	X5+1	<a href="#">21-0076</a>
6 SC70	X6SN+1	<a href="#">21-0077</a>
6 $\mu$ DFN	L611+2	<a href="#">21-0147</a>

# 1 $\mu$ A, 2Mbps, Low-Voltage Level Translators in SC70 and $\mu$ DFN

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/00	Initial release	—
3	5/09	Updated <i>Ordering Information</i> , style edits.	1, 5, 8, 9, 11

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

10 **Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600**