

## *Bidirectional Voltage Level Translator for Open-Drain and Push-Pull Applications*

### UM2001P SOT363

#### General Description

The UM2001P is a bidirectional voltage level translator operational from 1.0V to 3.6V ( $V_{CCA}$ ) and 1.8V to 5.5V ( $V_{CCB}$ ), which allows bidirectional voltage translations between 1.0V and 5V without the need for a direction pin in open-drain or push-pull applications. The UM2001P is a 1-bit level translator. Its transmission speeds are below 33MHz for an open-drain system with a 50pF capacitance and a pull-up resistor of 197 $\Omega$ .

The low ON-state resistance ( $R_{on}$ ) of the switch allows connections to be made with minimal propagation delay. When EN is high, the translator switch is ON, and the A I/O is connected to the B I/O, allowing bidirectional data flow between ports. When EN is low, the translator switch is off, and a high-impedance state exists between ports.

The translators provide excellent ESD protection to lower voltage devices, and at the same time protect less ESD-resistant devices.

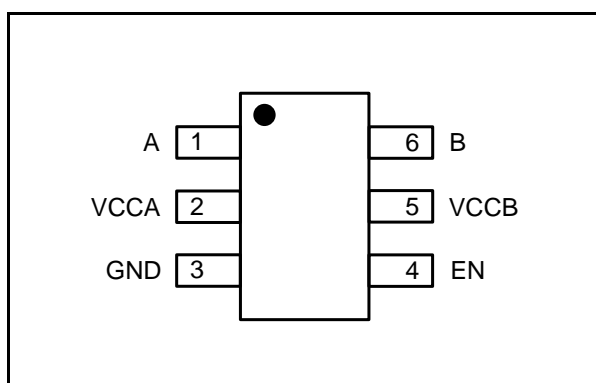
#### Applications

- SPI, MICROWIRE, and I<sup>2</sup>C Level Translation
- Low-Voltage ASIC Level Translation
- Smart Card Readers
- Cell-phone Cradles
- Portable POS Systems
- Portable Communication Devices
- Low-Cost Serial Interfaces
- Cell-Phones
- GPS
- Telecommunications Equipment
- Consumer Electronics
- Household Appliances

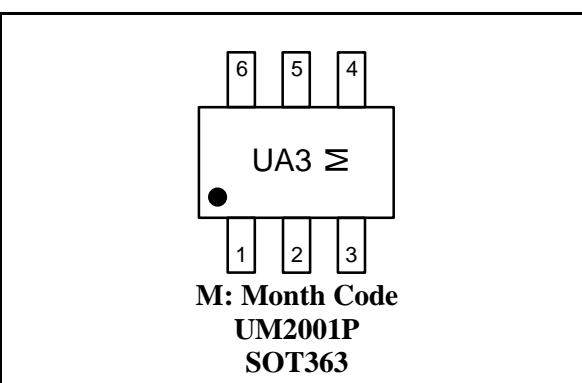
#### Features

- Provides Bidirectional Voltage Translation with No Direction Pin
- Less than 1.5ns Maximum Propagation Delay
- Low 3.5 $\Omega$  ON-State Connection between Input and Output Ports Provides Less Signal Distortion
- 5V Tolerant I/O Ports to Support Mixed-Mode Signal Operation
- High-Impedance A and B Pins for EN=LOW
- Latch up Free Operation
- Flow through Pinout for Ease of Printed-Circuit Board Trace Routing
- ESD Protection Exceeds:  
4kV HBM per JESD22-A114
- Package Offered: SOT363

#### Pin Configurations



#### Top View



## Pin Description

Pin Number	Symbol	Function
1	A	Low-voltage side; connected to VCCA through a pull-up resistor
2	VCCA	Low-voltage side reference supply voltage for A
3	GND	Ground (0V)
4	EN	Switch enable input; connected to VCCB and pulled-up through a high resistor
5	VCCB	High-voltage side reference supply voltage for B
6	B	High-voltage side; connected to VCCB through a pull-up resistor

## Ordering Information

Part Number	Packaging Type	Marking Code	Shipping Qty
UM2001P	SOT363	UA3	3000pcs/7Inch Tape & Reel

## Absolute Maximum Ratings (Note 1)

Over operating free-air temperature range (unless otherwise noted)

Symbol	Parameter	Value	Unit	
V <sub>CCA</sub>	Reference Voltage (A)	-0.5 to +6	V	
V <sub>CCB</sub>	Reference Voltage (B)	-0.5 to +6	V	
V <sub>I</sub>	Input Voltage	-0.5 (Note 2) to +6	V	
V <sub>I/O</sub>	Voltage on an Input/Output Pin	-0.5 (Note 2) to +6	V	
I <sub>CH</sub>	Channel Current (DC)	+128	mA	
I <sub>IK</sub>	Input Clamp Current	V <sub>I</sub> < 0V	-50	mA
T <sub>STG</sub>	Storage Temperature	-65 to +150	°C	

Note 1: 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 under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Note 2: The input and input/output negative voltage ratings may be exceeded if the input and input/output clamp current ratings are observed.

**Recommended Operating Conditions**

Symbol	Parameter	Conditions	Min	Max	Unit
$V_{I/O}$	Voltage on an Input/Output Pin	A, B	0	5.5	V
$V_{CCA}$ (Note 3)	Reference Voltage (A)	VCCA	0	5.5	V
$V_{CCB}$ (Note 3)	Reference Voltage (B)	VCCB	0	5.5	V
$V_{I(EN)}$	Input Voltage on Pin EN		0	5.5	V
$I_{sw(pass)}$	Pass Switch Current			64	mA
$T_{AMB}$	Ambient Temperature	Operating in Free-Air	-40	+85	°C

Note 3:  $V_{CCA} \leq V_{CCB} - 1V$  for best results in level shifting applications.

**Electrical Characteristics**

$T_{AMB} = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ (Note 4)	Max	Unit
$V_{IK}$	Input Clamping Voltage	$I_I = -18mA$ ; $V_{I(EN)} = 0V$			-1.2	V
$I_{IH}$	HIGH-Level Input Current	$V_I = 5V$ ; $V_{I(EN)} = 0V$			5	$\mu A$
$C_{i(EN)}$	Input Capacitance on Pin EN	$V_I = 0V$ or $3V$		12		pF
$C_{io(off)}$	Off-State Input/Output Capacitance	A, B; $V_O = 0V$ or $3V$ ; $V_{I(EN)} = 0V$		10	12	pF
$C_{io(on)}$	On-State Input/Output Capacitance	A, B; $V_O = 0V$ or $3V$ ; $V_{I(EN)} = 3V$		8	12.5 (Note 5)	pF
$R_{on}$	ON-State Resistance (Note 6)	A, B; $V_I = 0V$ ; $I_O = 64mA$ ; $V_{I(EN)} = 4.5V$ (Note 7)	1	2.5	5.0	$\Omega$
		A, B; $V_I = 2.4V$ ; $I_O = 15mA$ ; $V_{I(EN)} = 4.5V$		4.5	7.5	

Note 4: All typical values are at  $T_{AMB} = 25^{\circ}C$ .

Note 5: Not production tested, maximum value based on characterization data of typical parts.

Note 6: Measured by the voltage drop between the A and B terminals at the indicated current through the switch. ON-state resistance is determined by the lowest voltage of the two terminals.

Note 7: Guaranteed by design.

**Switching Characteristics (Translating Down)**

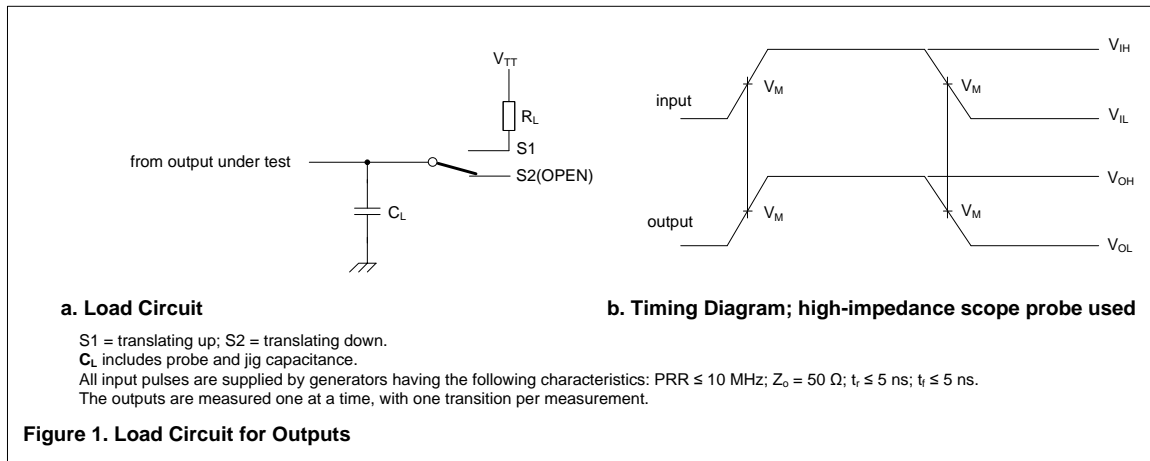
Over recommended operating free-air temperature range (unless otherwise noted). Values guaranteed by design.

Symbol	Parameter	Test Conditions	C <sub>L</sub> =50pF		C <sub>L</sub> =30pF		C <sub>L</sub> =15pF		Unit
			Min	Max	Min	Max	Min	Max	
V <sub>I(EN)</sub> =3.3V; V <sub>IH</sub> =3.3V; V <sub>IL</sub> =0V; V <sub>M</sub> =1.15V (see Figure 1).									
t <sub>PLH</sub>	LOW to HIGH Propagation Delay	from (Input) B to (Output) A	0	3.5	0	2.7	0	2.2	ns
t <sub>PHL</sub>	HIGH to LOW Propagation Delay		0	3.5	0	3.0	0	2.3	ns
V <sub>I(EN)</sub> =2.5V; V <sub>IH</sub> =2.5V; V <sub>IL</sub> =0V; V <sub>M</sub> =0.75V (see Figure 1).									
t <sub>PLH</sub>	LOW to HIGH Propagation Delay	from (Input) B to (Output) A	0	3.5	0	2.7	0	2.2	ns
t <sub>PHL</sub>	HIGH to LOW Propagation Delay		0	4.0	0	3.0	0	2.3	ns

**Switching Characteristics (Translating Up)**

Over recommended operating free-air temperature range (unless otherwise noted). Values guaranteed by design.

Symbol	Parameter	Test Conditions	C <sub>L</sub> =50pF		C <sub>L</sub> =30pF		C <sub>L</sub> =15pF		Unit
			Min	Max	Min	Max	Min	Max	
V <sub>I(EN)</sub> =3.3V; V <sub>IH</sub> =2.3V; V <sub>IL</sub> =0V; V <sub>TT</sub> =3.3V; V <sub>M</sub> =1.15V; R <sub>L</sub> =300Ω (see Figure 1).									
t <sub>PLH</sub>	LOW to HIGH Propagation Delay	from (Input) A to (Output) B	0	3.35	0	2.5	0	2.0	ns
t <sub>PHL</sub>	HIGH to LOW Propagation Delay		0	4.35	0	3.25	0	2.4	ns
V <sub>I(EN)</sub> =2.5V; V <sub>IH</sub> =1.5V; V <sub>IL</sub> =0V; V <sub>TT</sub> =2.5V; V <sub>M</sub> =0.75V; R <sub>L</sub> =300Ω (see Figure 1).									
t <sub>PLH</sub>	LOW to HIGH Propagation Delay	from (Input) A to (Output) B	0	3.35	0	2.5	0	2.0	ns
t <sub>PHL</sub>	HIGH to LOW Propagation Delay		0	4.5	0	3.5	0	2.5	ns



## Applications Information

### Detail Description

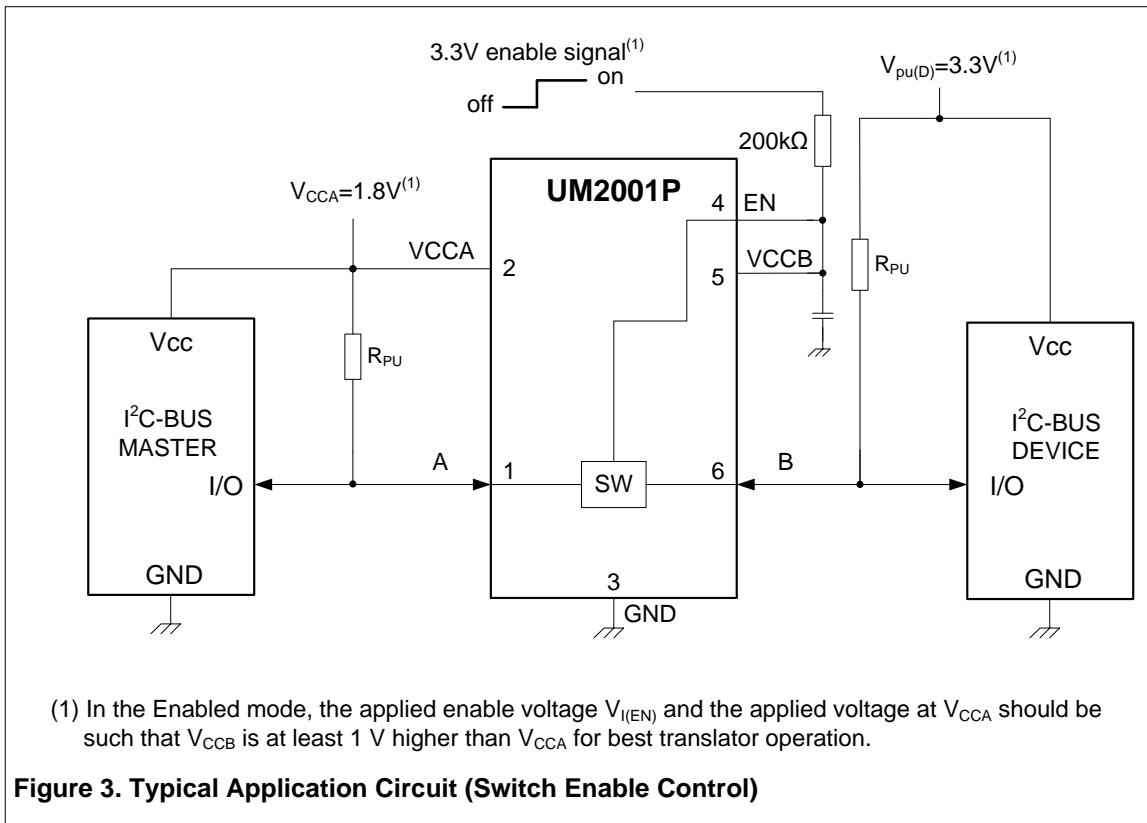
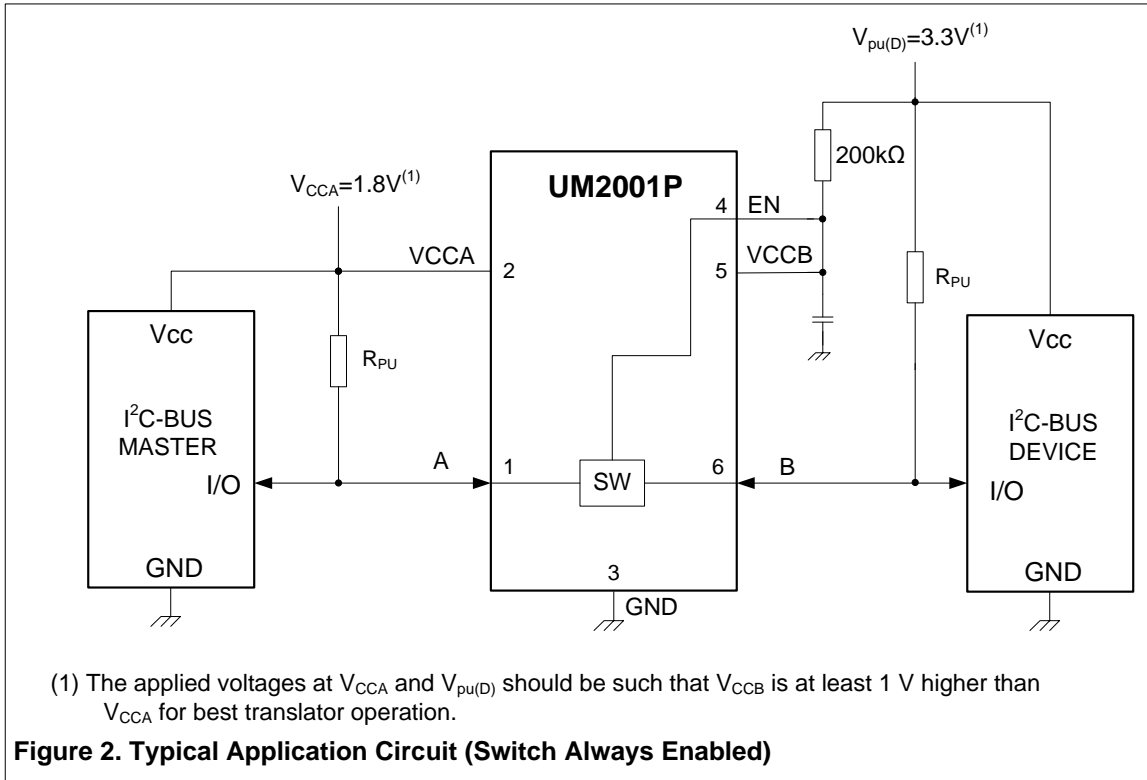
The UM2001P is a bidirectional voltage level translator operational from 1.0V to 3.6V ( $V_{CCA}$ ) and 1.8V to 5.5V ( $V_{CCB}$ ), which allows bidirectional voltage translations between 1.0V and 5V without the need for a direction pin in open-drain or push-pull applications.

When the A or B port is LOW, the clamp is in the ON-state and a low resistance connection exists between the A and B ports. The low ON-state resistance ( $R_{on}$ ) of the switch allows connections to be made with minimal propagation delay. Assuming the higher voltage is on the B port when the B port is HIGH, the voltage on the A port is limited to the voltage set by  $V_{CCA}$ . When the A port is HIGH, the B port is pulled to the drain pull-up supply voltage ( $V_{pu(D)}$ ) by the pull-up resistors. This functionality allows a seamless translation between higher and lower voltages selected by the user without the need for directional control.

When EN is HIGH, the translator switch is on, and the A I/O is connected to the B I/O, allowing bidirectional data flow between ports. When EN is LOW, the translator switch is off, and a high-impedance state exists between ports. The EN input circuit is designed to be supplied by  $V_{CCB}$ . To ensure the high-impedance state during power-up or power-down, EN must be LOW.

All channels have the same electrical characteristics and there is minimal deviation from one output to another in voltage or propagation delay. This is a benefit over discrete transistor voltage translation solutions, since the fabrication of the switch is symmetrical.

**Enable and Disable**



## Bidirectional Translation

For the bidirectional clamping configuration (higher voltage to lower voltage or lower voltage to higher voltage), the EN input must be connected to VCCB and both pins pulled to HIGH side  $V_{pu(D)}$  through a pull-up resistor (typically 200kΩ). This allows VCCB to regulate the EN input. A filter capacitor on VCCB is recommended. The master output driver can be totem pole or open-drain (pull-up resistors may be required) and the slave device output can be totem pole or open-drain (pull-up resistors are required to pull the B output to  $V_{pu(D)}$ ). However, if either output is totem pole, data must be unidirectional or the outputs must be 3-stateable and be controlled by some direction-control mechanism to prevent HIGH-to-LOW contentions in either direction. If both outputs are open-drain, no direction control is needed.

The reference supply voltage ( $V_{CCA}$ ) is connected to the processor core power supply voltage. When VCCB is connected through a 200kΩ resistor to a 3.3V to 5.5V  $V_{pu(D)}$  power supply, and  $V_{CCA}$  is set between 1.0V and ( $V_{pu(D)} - 1V$ ), the output of A has a maximum output voltage equal to  $V_{CCA}$ , and the output of B has a maximum output voltage equal to  $V_{pu(D)}$ .

## Application Operating Conditions

Refer to Figure 2

Symbol	Parameter	Conditions	Min	Typ (Note 8)	Max	Unit
$V_{CCB}$	Reference Voltage (B)		$V_{CCA}+0.6$	2.1	5	V
$V_{I(EN)}$	Input Voltage on Pin EN		$V_{CCA}+0.6$	2.1	5	V
$V_{CCA}$	Reference Voltage (A)		0	1.5	4.4	V
$I_{sw(pass)}$	Pass Switch Current			14		mA
$I_{ref}$	Reference Current	Transistor		5		μA
$T_{AMB}$	Ambient Temperature	Operating in Free-Air	-40		+85	°C

Note 8: All typical values are at  $T_{AMB}=25^{\circ}C$ .

## Sizing Pull-Up Resistor

The pull-up resistor value needs to limit the current through the pass transistor when it is in the ON state to about 15mA. This ensures a pass voltage of 260mV to 350mV. If the current through the pass transistor is higher than 15mA, the pass voltage also is higher in the ON state. To set the current through each pass transistor at 15mA, the pull-up resistor value is calculated as:

$$R_{PU} = \frac{V_{pu(D)} - 0.35V}{0.015A}$$

The table below summarizes resistor reference voltages and currents at 15mA, 10mA, and 3mA. The resistor values shown in the +10 % column or a larger value should be used to ensure that the pass voltage of the transistor would be 350 mV or less. The external driver must be able to sink the total current from the resistors on both sides of the UM2001P device at 0.175V, although the 15mA only applies to current flowing through the UM2001P device.

## Pull-Up Resistor Values

Calculated for  $V_{OL}=0.35V$ ; assumes output driver  $V_{OL}=0.175V$  at stated current.

$V_{pu(D)}$	Pull-Up Resistor Value ( $\Omega$ )					
	15mA		10mA		3mA	
	Nominal	+10% (Note 9)	Nominal	+10% (Note 9)	Nominal	+10% (Note 9)
5V	310	341	465	512	1550	1705
3.3V	197	217	295	325	983	1082
2.5V	143	158	215	237	717	788
1.8V	97	106	145	160	483	532
1.5V	77	85	115	127	383	422
1.2V	57	63	85	94	283	312

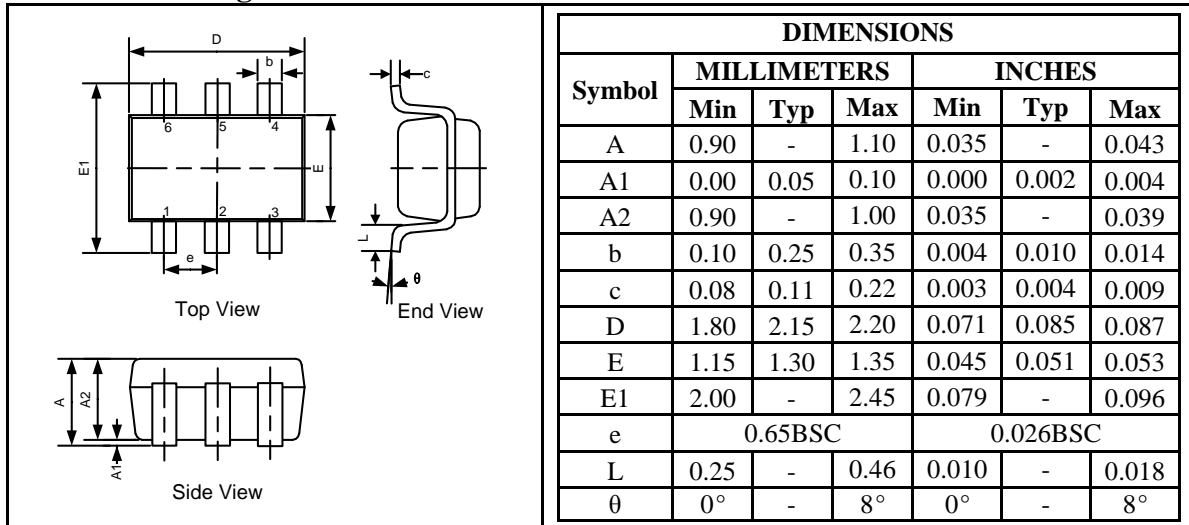
Note 9: +10% to compensate for  $V_{CC}$  range and resistor tolerance.



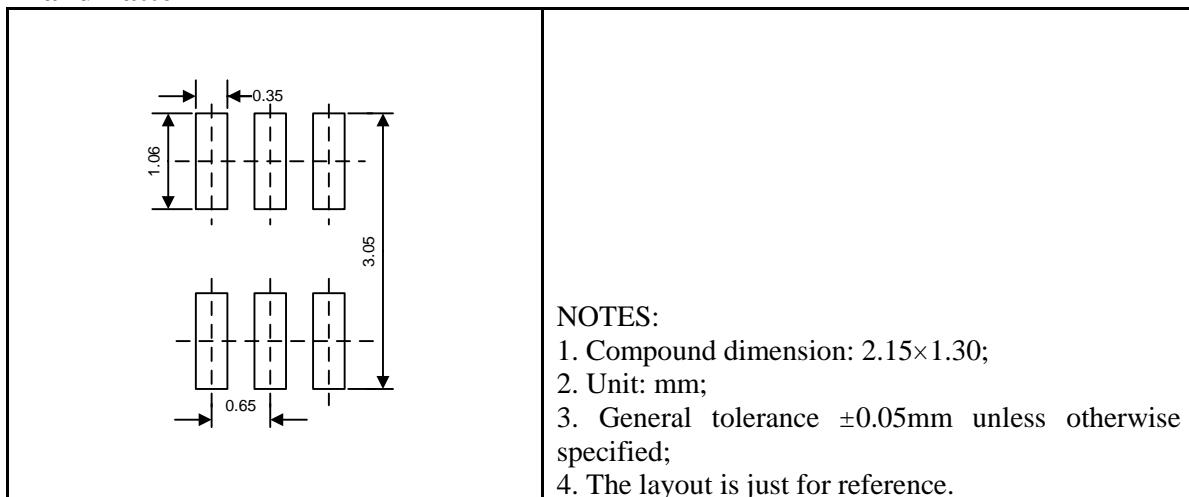
## Package Information

### UM2001P SOT363

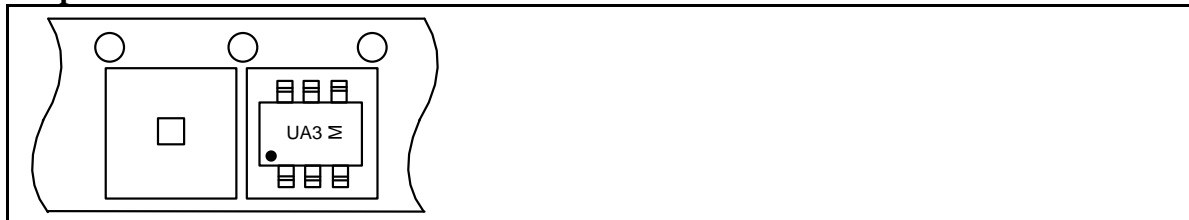
#### Outline Drawing



#### Land Pattern



#### Tape and Reel Orientation



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Union Semiconductor, Inc

Add: Unit 606, No.570 Shengxia Road, Shanghai 201210

Tel: 021-51093966

Fax: 021-51026018

Website: [www.union-ic.com](http://www.union-ic.com)