

TOSHIBA CMOS Digital Integrated Circuit Silicon Monolithic

# TC74VCX16652FT

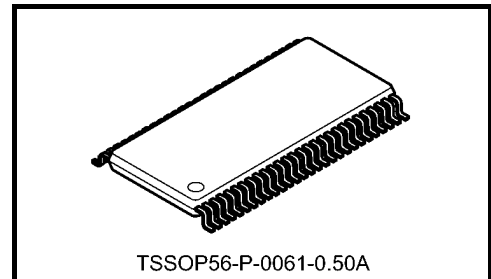
## Low-Voltage 16-Bit Bus Transceiver/Register with 3.6-V Tolerant Inputs and Outputs

The TC74VCX16652FT is a high-performance CMOS 16-bit bus transceiver/register. Designed for use in 1.8-V, 2.5-V or 3.3-V systems, it achieves high-speed operation while maintaining the CMOS low power dissipation.

It is also designed with overvoltage tolerant inputs and outputs up to 3.6 V.

This device is bus transceiver with 3-state outputs, D-type flip-flops, and control circuitry arranged for multiplexed transmission of data directly from the internal registers.

All inputs are equipped with protection circuits against static discharge.



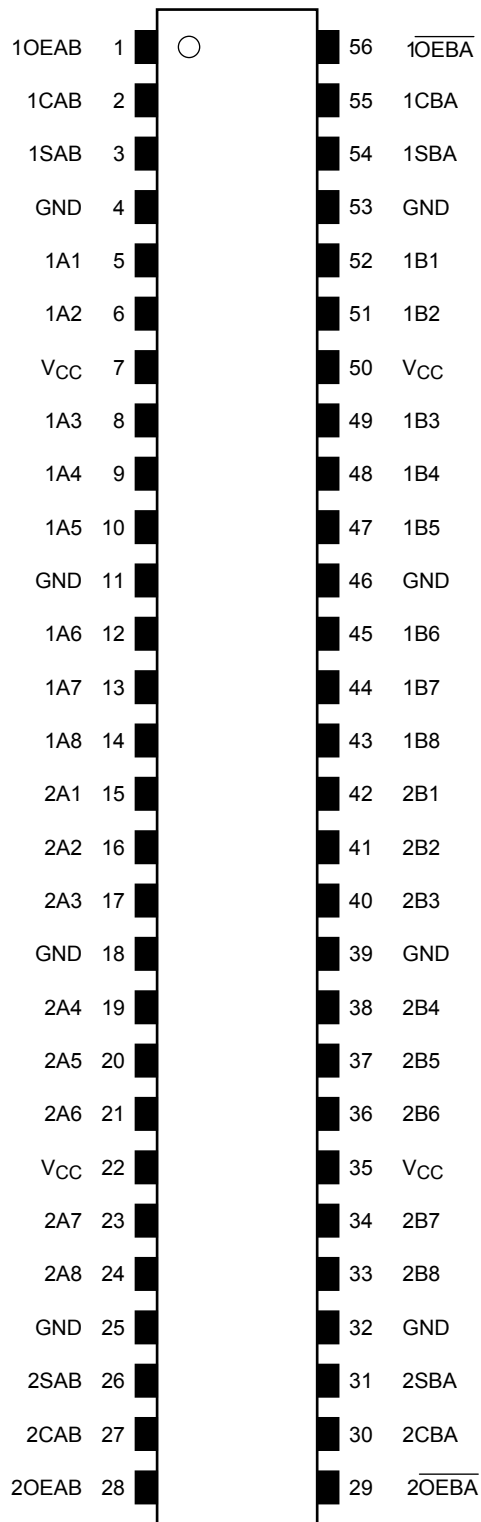
Weight: 0.25 g (typ.)

### Features (Note)

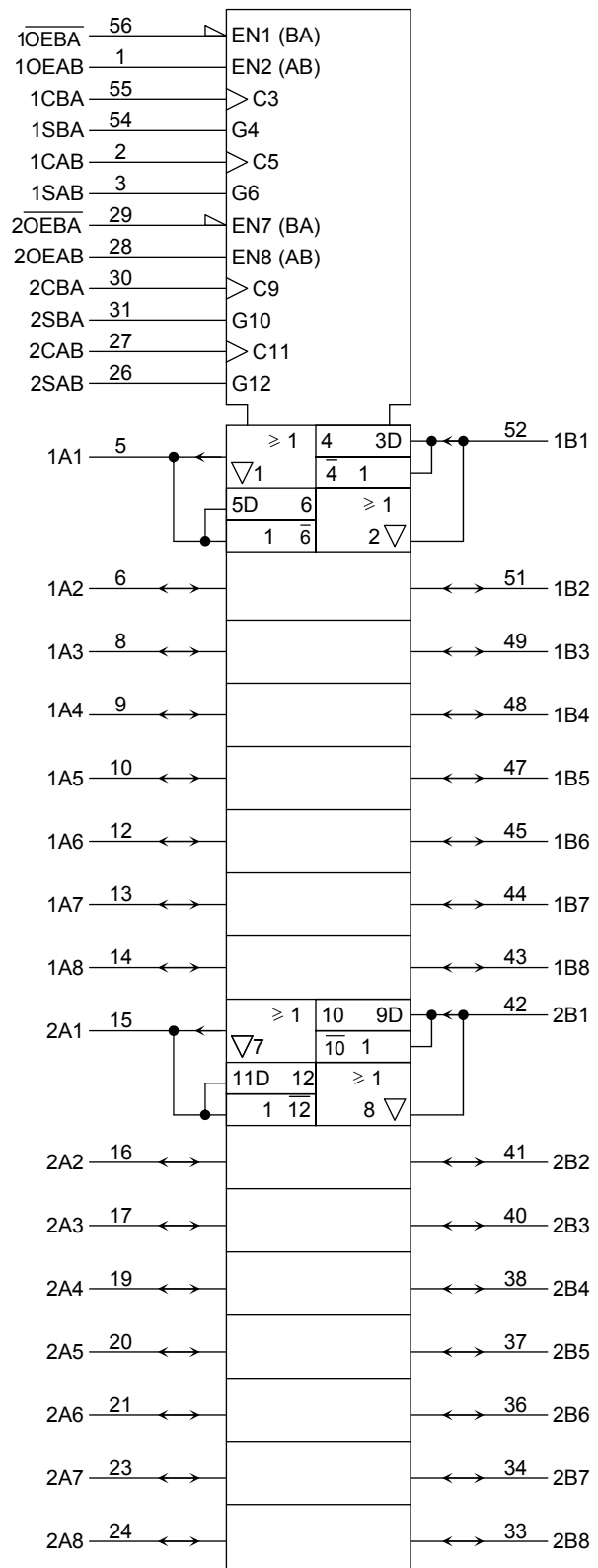
- Low-voltage operation:  $V_{CC} = 1.8$  to  $3.6$  V
- High-speed operation:  $t_{pd} = 2.9$  ns (max) ( $V_{CC} = 3.0$  to  $3.6$  V)  
:  $t_{pd} = 3.5$  ns (max) ( $V_{CC} = 2.3$  to  $2.7$  V)  
:  $t_{pd} = 7.0$  ns (max) ( $V_{CC} = 1.8$  V)
- Output current:  $I_{OH}/I_{OL} = \pm 24$  mA (min) ( $V_{CC} = 3.0$  V)  
:  $I_{OH}/I_{OL} = \pm 18$  mA (min) ( $V_{CC} = 2.3$  V)  
:  $I_{OH}/I_{OL} = \pm 6$  mA (min) ( $V_{CC} = 1.8$  V)
- Latch-up performance:  $-300$  mA
- ESD performance: Machine model  $\geq \pm 200$  V  
Human body model  $\geq \pm 2000$  V
- Package: TSSOP
- Bidirectional interface between 2.5 V and 3.3 V signals.
- 3.6-V tolerant function and power-down protection is provided on all inputs and outputs

Note: Do not apply a signal to any bus pins when it is in the output mode. Damage may result.  
All floating (high impedance) bus pins must have their input level fixed by means of pull-up or pull-down resistors.







## Pin Assignment (top view)



## IEC Logic Symbol



## Truth Table

Control Inputs						Bus		Function	
OEAB	$\overline{\text{OEBA}}$	CAB	CBA	SAB	SBA	A	B		
L	H	X*	X*	X	X	Input	Input	The output functions of A and B Busses are disabled.	
		Z	Z			Z	Z		
				X	X	X	X	Both A and B Busses are used as inputs to the internal flip-flops. Data on the Bus will be stored on the rising edge of the Clock.	
		X*	X*	L	X	Input	Output	The data on the A bus are displayed on the B bus.	
H	H	X*	X*	L	X	L	L		
			X*	L	X	L	L	The data on the A bus are displayed on the B Bus, and are stored into the A storage flip-flops on the rising edge of CAB.	
		X*	X*	H	X	X	Qn		The data in the A storage flop-flops are displayed on the B Bus.
			X*	H	X	L	L	L	The data on the A Bus are stored into the A storage flip-flops on the rising edge of CAB, and the stored data propagate directly onto the B Bus.
X*	X*	H	X	H	H	H			
L	L	X*	X*	X	L	Output	Input	The data on the B Bus are displayed on the A bus.	
		L	L			L	L		
		X*		X	L	L	L	L	The data on the B Bus are displayed on the A Bus, and are stored into the B storage flip-flops on the rising edge of CBA.
		X*	X*	X	H	Qn	X	The data in the B storage flip-flops are displayed on the A Bus.	
X*		X	H	L	L	L	The data on the B Bus are stored into the B storage flip-flops on the rising edge of CBA, and the stored data propagate directly onto the A Bus.		
X*	X*	X	H	H	H	H			
H	L	X*	X*	H	H	Output	Output	The data in the A storage flop-flops are displayed on the B Bus, and the data in the B storage flop-flops are displayed on the A.	
		Qn	Qn			Qn	Qn		

X: Don't care

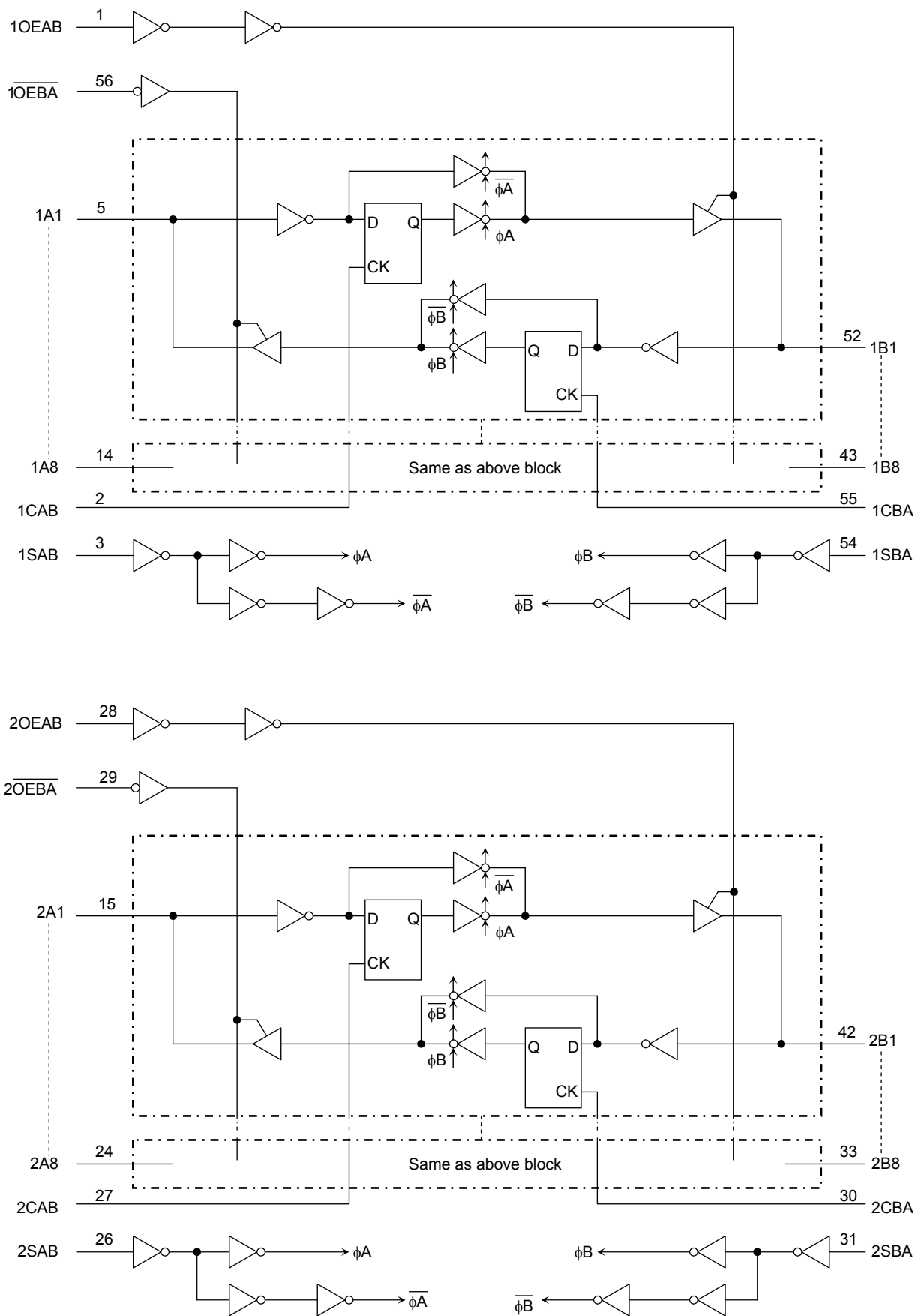
Z: High impedance

Qn: The data stored into the internal flip-flops by most recent low to high transition of the clock inputs.

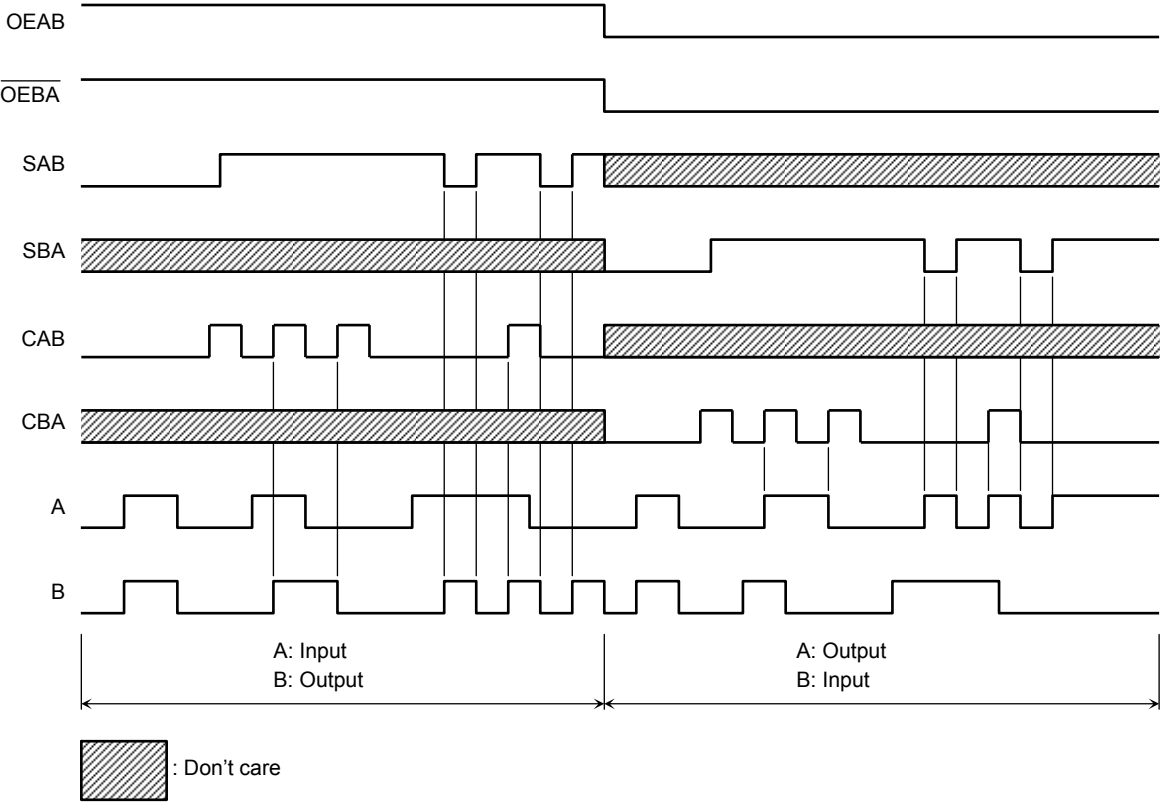
\*: The clocks are not internally gated with either OEAB or  $\overline{\text{OEBA}}$ .

Therefore, data on the A and/or B busses may be clocked into the storage flip-flops at any time.

## System Diagram



Timing Chart



## Absolute Maximum Ratings (Note 1)

Characteristics	Symbol	Rating	Unit
Power supply voltage	$V_{CC}$	-0.5 to 4.6	V
DC input voltage (CAB, CBA, SAB, SBA, OEAB, OEBA)	$V_{IN}$	-0.5 to 4.6	V
DC bus I/O voltage	$V_{I/O}$	-0.5 to 4.6 (Note 2)	V
		-0.5 to $V_{CC} + 0.5$ (Note 3)	
Input diode current	$I_{IK}$	-50	mA
Output diode current	$I_{OK}$	$\pm 50$ (Note 4)	mA
DC output current	$I_{OUT}$	$\pm 50$	mA
Power dissipation	$P_D$	400	mW
DC $V_{CC}$ /ground current per supply pin	$I_{CC}/I_{GND}$	$\pm 100$	mA
Storage temperature	$T_{stg}$	-65 to 150	$^{\circ}C$

Note 1: Exceeding any of the absolute maximum ratings, even briefly, lead to deterioration in IC performance or even destruction.

Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings and the operating ranges.

Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Note 2: OFF state

Note 3: High or low state.  $I_{OUT}$  absolute maximum rating must be observed.

Note 4:  $V_{OUT} < GND$ ,  $V_{OUT} > V_{CC}$

## Operating Ranges (Note 1)

Characteristics	Symbol	Rating	Unit
Power supply voltage	$V_{CC}$	1.8 to 3.6	V
		1.2 to 3.6 (Note 2)	
Input voltage (CAB, CBA, SAB, SBA, OEAB, OEBA)	$V_{IN}$	-0.3 to 3.6	V
Bus I/O voltage	$V_{I/O}$	0 to 3.6 (Note 3)	V
		0 to $V_{CC}$ (Note 4)	
Output current	$I_{OH}/I_{OL}$	$\pm 24$ (Note 5)	mA
		$\pm 18$ (Note 6)	
		$\pm 6$ (Note 7)	
Operating temperature	$T_{opr}$	-40 to 85	$^{\circ}C$
Input rise and fall time	$dt/dv$	0 to 10 (Note 8)	ns/V

Note 1: The operating ranges must be maintained to ensure the normal operation of the device.  
Unused inputs must be tied to either  $V_{CC}$  or GND.

Note 2: Data retention only

Note 3: OFF state

Note 4: High or low state

Note 5:  $V_{CC} = 3.0$  to  $3.6$  V

Note 6:  $V_{CC} = 2.3$  to  $2.7$  V

Note 7:  $V_{CC} = 1.8$  V

Note 8:  $V_{IN} = 0.8$  to  $2.0$  V,  $V_{CC} = 3.0$  V

## Electrical Characteristics

### DC Characteristics (Ta = -40 to 85°C, 2.7 V < VCC ≤ 3.6 V)

Characteristics		Symbol	Test Condition		VCC (V)	Min	Max	Unit
Input voltage	H-level	V <sub>IH</sub>	—		2.7 to 3.6	2.0	—	V
	L-level	V <sub>IL</sub>	—		2.7 to 3.6	—	0.8	
Output voltage	H-level	V <sub>OH</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OH</sub> = -100 μA	2.7 to 3.6	V <sub>CC</sub> - 0.2	—	V
				I <sub>OH</sub> = -12 mA	2.7	2.2	—	
				I <sub>OH</sub> = -18 mA	3.0	2.4	—	
				I <sub>OH</sub> = -24 mA	3.0	2.2	—	
	L-level	V <sub>OL</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OL</sub> = 100 μA	2.7 to 3.6	—	0.2	
				I <sub>OL</sub> = 12 mA	2.7	—	0.4	
				I <sub>OL</sub> = 18 mA	3.0	—	0.4	
				I <sub>OL</sub> = 24 mA	3.0	—	0.55	
Input leakage current		I <sub>IN</sub>	V <sub>IN</sub> = 0 to 3.6 V		2.7 to 3.6	—	±5.0	μA
3-state output OFF state current		I <sub>OZ</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> V <sub>OUT</sub> = 0 to 3.6 V		2.7 to 3.6	—	±10.0	μA
Power-off leakage current		I <sub>OFF</sub>	V <sub>IN</sub> , V <sub>OUT</sub> = 0 to 3.6 V		0	—	10.0	μA
Quiescent supply current		I <sub>CC</sub>	V <sub>IN</sub> = V <sub>CC</sub> or GND		2.7 to 3.6	—	20.0	μA
			V <sub>CC</sub> ≤ (V <sub>IN</sub> , V <sub>OUT</sub> ) ≤ 3.6 V		2.7 to 3.6	—	±20.0	
Increase in I <sub>CC</sub> per input		ΔI <sub>CC</sub>	V <sub>IH</sub> = V <sub>CC</sub> - 0.6 V		2.7 to 3.6	—	750	

### DC Characteristics (Ta = -40 to 85°C, 2.3 V ≤ VCC ≤ 2.7 V)

Characteristics		Symbol	Test Condition		VCC (V)	Min	Max	Unit
Input voltage	H-level	V <sub>IH</sub>	—		2.3 to 2.7	1.6	—	V
	L-level	V <sub>IL</sub>	—		2.3 to 2.7	—	0.7	
Output voltage	H-level	V <sub>OH</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OH</sub> = -100 μA	2.3 to 2.7	V <sub>CC</sub> - 0.2	—	V
				I <sub>OH</sub> = -6 mA	2.3	2.0	—	
				I <sub>OH</sub> = -12 mA	2.3	1.8	—	
				I <sub>OH</sub> = -18 mA	2.3	1.7	—	
	L-level	V <sub>OL</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OL</sub> = 100 μA	2.3 to 2.7	—	0.2	
				I <sub>OL</sub> = 12 mA	2.3	—	0.4	
				I <sub>OL</sub> = 18 mA	2.3	—	0.6	
				Input leakage current		I <sub>IN</sub>	V <sub>IN</sub> = 0 to 3.6 V	
3-state output OFF state current		I <sub>OZ</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> V <sub>OUT</sub> = 0 to 3.6 V		2.3 to 2.7	—	±10.0	μA
Power-off leakage current		I <sub>OFF</sub>	V <sub>IN</sub> , V <sub>OUT</sub> = 0 to 3.6 V		0	—	10.0	μA
Quiescent supply current		I <sub>CC</sub>	V <sub>IN</sub> = V <sub>CC</sub> or GND		2.3 to 2.7	—	20.0	μA
			V <sub>CC</sub> ≤ (V <sub>IN</sub> , V <sub>OUT</sub> ) ≤ 3.6 V		2.3 to 2.7	—	±20.0	

## DC Characteristics (Ta = -40 to 85°C, 1.8 V ≤ VCC < 2.3 V)

Characteristics		Symbol	Test Condition		VCC (V)	Min	Max	Unit
Input voltage	H-level	V <sub>IH</sub>	—		1.8 to 2.3	0.7 × V <sub>CC</sub>	—	V
	L-level	V <sub>IL</sub>	—		1.8 to 2.3	—	0.2 × V <sub>CC</sub>	
Output voltage	H-level	V <sub>OH</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OH</sub> = -100 μA	1.8	V <sub>CC</sub> - 0.2	—	V
				I <sub>OH</sub> = -6 mA	1.8	1.4	—	
	L-level	V <sub>OL</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OL</sub> = 100 μA	1.8	—	0.2	
				I <sub>OL</sub> = 6 mA	1.8	—	0.3	
Input leakage current		I <sub>IN</sub>	V <sub>IN</sub> = 0 to 3.6 V		1.8	—	±5.0	μA
3-state output OFF state current		I <sub>OZ</sub>	V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> V <sub>OUT</sub> = 0 to 3.6 V		1.8	—	±10.0	μA
Power-off leakage current		I <sub>OFF</sub>	V <sub>IN</sub> , V <sub>OUT</sub> = 0 to 3.6 V		0	—	10.0	μA
Quiescent supply current		I <sub>CC</sub>	V <sub>IN</sub> = V <sub>CC</sub> or GND		1.8	—	20.0	μA
			V <sub>CC</sub> ≤ (V <sub>IN</sub> , V <sub>OUT</sub> ) ≤ 3.6 V		1.8	—	±20.0	



## AC Characteristics (Ta = -40 to 85°C, input: tr = tf = 2.0 ns, CL = 30 pF, RL = 500 Ω) (Note 1)

Characteristics	Symbol	Test Condition	VCC (V)	Min	Max	Unit
Maximum clock frequency	f <sub>max</sub>	Figure 1, Figure 3	1.8	100	—	MHz
			2.5 ± 0.2	200	—	
			3.3 ± 0.3	250	—	
Propagation delay time (An, Bn-Bn, An)	t <sub>pLH</sub> t <sub>pHL</sub>	Figure 1, Figure 2	1.8	1.5	7.0	ns
			2.5 ± 0.2	0.8	3.5	
			3.3 ± 0.3	0.6	2.9	
Propagation delay time (CAB, CBA-Bn, An)	t <sub>pLH</sub> t <sub>pHL</sub>	Figure 1, Figure 3	1.8	1.5	8.8	ns
			2.5 ± 0.2	0.8	4.4	
			3.3 ± 0.3	0.6	3.2	
Propagation delay time (SAB, SBA-Bn, An)	t <sub>pLH</sub> t <sub>pHL</sub>	Figure 1, Figure 2	1.8	1.5	8.8	ns
			2.5 ± 0.2	0.8	4.4	
			3.3 ± 0.3	0.6	3.5	
Output enable time (OEAB, OEBA -An, Bn)	t <sub>pZL</sub> t <sub>pZH</sub>	Figure 1, Figure 4, Figure 5	1.8	1.5	9.8	ns
			2.5 ± 0.2	0.8	4.9	
			3.3 ± 0.3	0.6	3.8	
Output disable time (OEAB, OEBA -An, Bn)	t <sub>pLZ</sub> t <sub>pHZ</sub>	Figure 1, Figure 4, Figure 5	1.8	1.5	8.1	ns
			2.5 ± 0.2	0.8	4.5	
			3.3 ± 0.3	0.6	3.9	
Minimum pulse width	t <sub>w</sub> (H) t <sub>w</sub> (L)	Figure 1, Figure 3	1.8	4.0	—	ns
			2.5 ± 0.2	1.5	—	
			3.3 ± 0.3	1.5	—	
Minimum setup time	t <sub>s</sub>	Figure 1, Figure 3	1.8	2.5	—	ns
			2.5 ± 0.2	1.5	—	
			3.3 ± 0.3	1.5	—	
Minimum hold time	t <sub>h</sub>	Figure 1, Figure 3	1.8	1.0	—	ns
			2.5 ± 0.2	1.0	—	
			3.3 ± 0.3	1.0	—	
Output to output skew	t <sub>osLH</sub> t <sub>osHL</sub>	(Note 2)	1.8	—	0.5	ns
			2.5 ± 0.2	—	0.5	
			3.3 ± 0.3	—	0.5	

Note 1: For C<sub>L</sub> = 50 pF, add approximately 300 ps to the AC maximum specification.

Note 2: Parameter guaranteed by design.

(t<sub>osLH</sub> = |t<sub>pLHm</sub> - t<sub>pLHn</sub>|, t<sub>osHL</sub> = |t<sub>pHLm</sub> - t<sub>pHLn</sub>|)

## Dynamic Switching Characteristics

( $T_a = 25^\circ\text{C}$ , input:  $t_r = t_f = 2.0 \text{ ns}$ ,  $C_L = 30 \text{ pF}$ ,  $R_L = 500 \Omega$ )

Characteristics	Symbol	Test Condition	V <sub>CC</sub> (V)	Typ.	Unit
Quiet output maximum dynamic V <sub>OL</sub>	V <sub>OLP</sub>	V <sub>IH</sub> = 1.8 V, V <sub>IL</sub> = 0 V (Note)	1.8	0.25	V
		V <sub>IH</sub> = 2.5 V, V <sub>IL</sub> = 0 V (Note)	2.5	0.6	
		V <sub>IH</sub> = 3.3 V, V <sub>IL</sub> = 0 V (Note)	3.3	0.8	
Quiet output minimum dynamic V <sub>OL</sub>	V <sub>OLV</sub>	V <sub>IH</sub> = 1.8 V, V <sub>IL</sub> = 0 V (Note)	1.8	-0.25	V
		V <sub>IH</sub> = 2.5 V, V <sub>IL</sub> = 0 V (Note)	2.5	-0.6	
		V <sub>IH</sub> = 3.3 V, V <sub>IL</sub> = 0 V (Note)	3.3	-0.8	
Quiet output minimum dynamic V <sub>OH</sub>	V <sub>OHV</sub>	V <sub>IH</sub> = 1.8 V, V <sub>IL</sub> = 0 V (Note)	1.8	1.5	V
		V <sub>IH</sub> = 2.5 V, V <sub>IL</sub> = 0 V (Note)	2.5	1.9	
		V <sub>IH</sub> = 3.3 V, V <sub>IL</sub> = 0 V (Note)	3.3	2.2	

Note: Parameter guaranteed by design.

## Capacitive Characteristics ( $T_a = 25^\circ\text{C}$ )

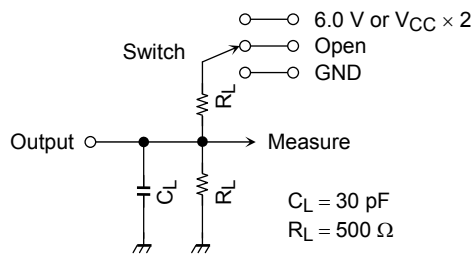
Characteristics	Symbol	Test Condition	V <sub>CC</sub> (V)	Typ.	Unit
Input capacitance	C <sub>IN</sub>	(OEAB, $\overline{\text{OEBA}}$ , CAB, CBA, SAB, SBA)	1.8, 2.5, 3.3	6	pF
Bus I/O capacitance	C <sub>I/O</sub>	An, Bn	1.8, 2.5, 3.3	7	pF
Power dissipation capacitance	C <sub>PD</sub>	f <sub>IN</sub> = 10 MHz (Note)	1.8, 2.5, 3.3	20	pF

Note: C<sub>PD</sub> is defined as the value of the internal equivalent capacitance which is calculated from the operating current consumption without load.

Average operating current can be obtained by the equation:

$$I_{CC(\text{opr})} = C_{PD} \cdot V_{CC} \cdot f_{IN} + I_{CC}/16 \text{ (per bit)}$$

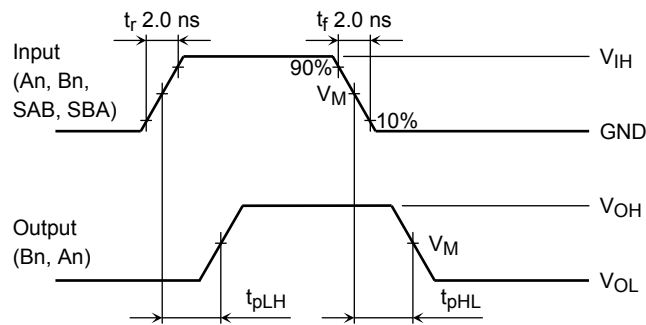
**AC Test Circuit**



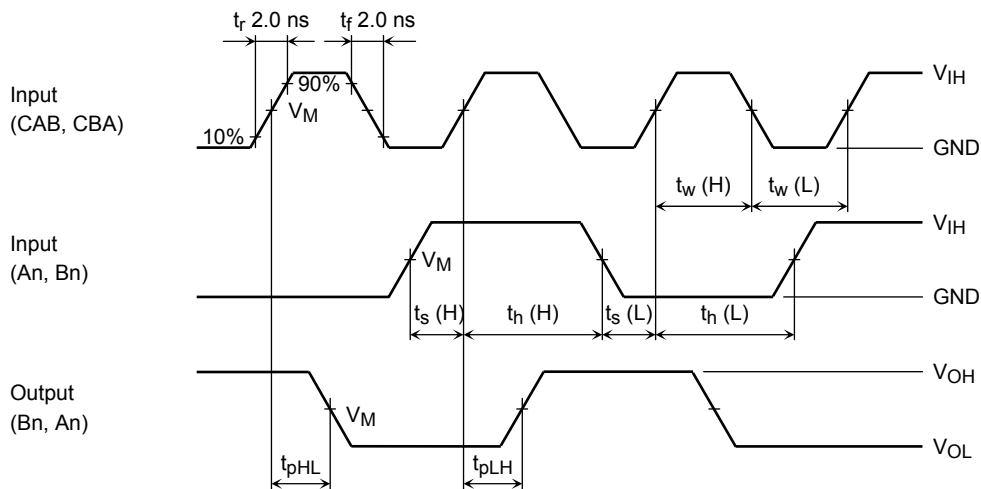
Parameter	Switch
$t_{pLH}$ , $t_{pHL}$	Open
$t_{pLZ}$ , $t_{pZL}$	6.0 V $V_{CC} \times 2$
	@ $V_{CC} = 3.3 \pm 0.3 \text{ V}$ @ $V_{CC} = 2.5 \pm 0.2 \text{ V}$ @ $V_{CC} = 1.8 \text{ V}$
$t_{pHZ}$ , $t_{pZH}$	GND

**Figure 1**

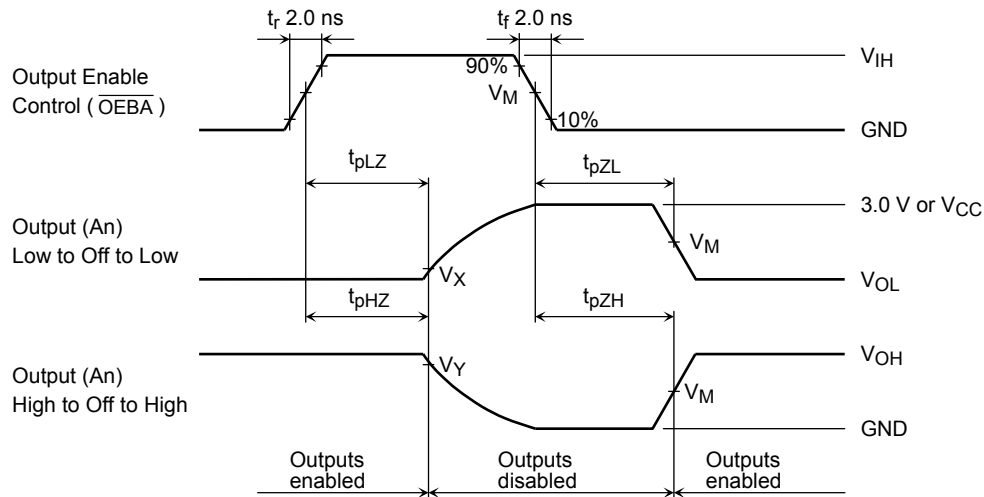
**AC Waveform**



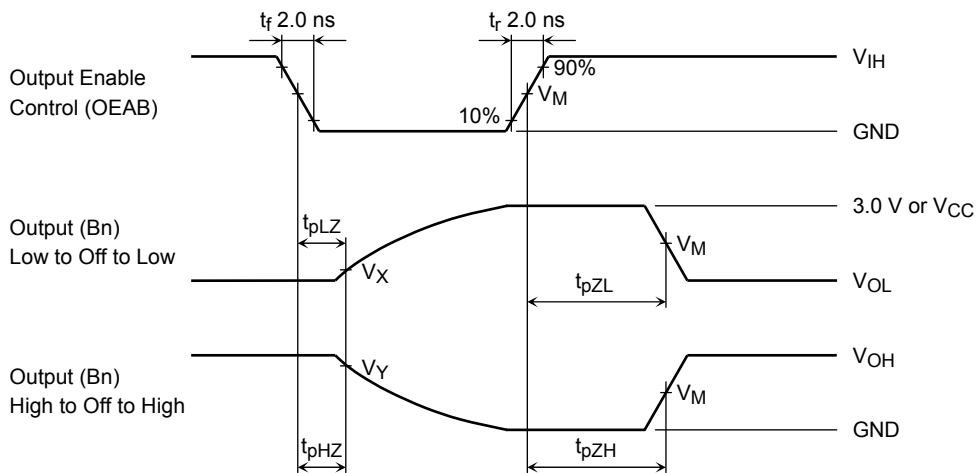
**Figure 2  $t_{pLH}$ ,  $t_{pHL}$**



**Figure 3  $t_{pLH}$ ,  $t_{pHL}$ ,  $t_w$ ,  $t_s$ ,  $t_h$**



**Figure 4**  $t_{pLZ}$ ,  $t_{pHZ}$ ,  $t_{pZL}$ ,  $t_{pZH}$



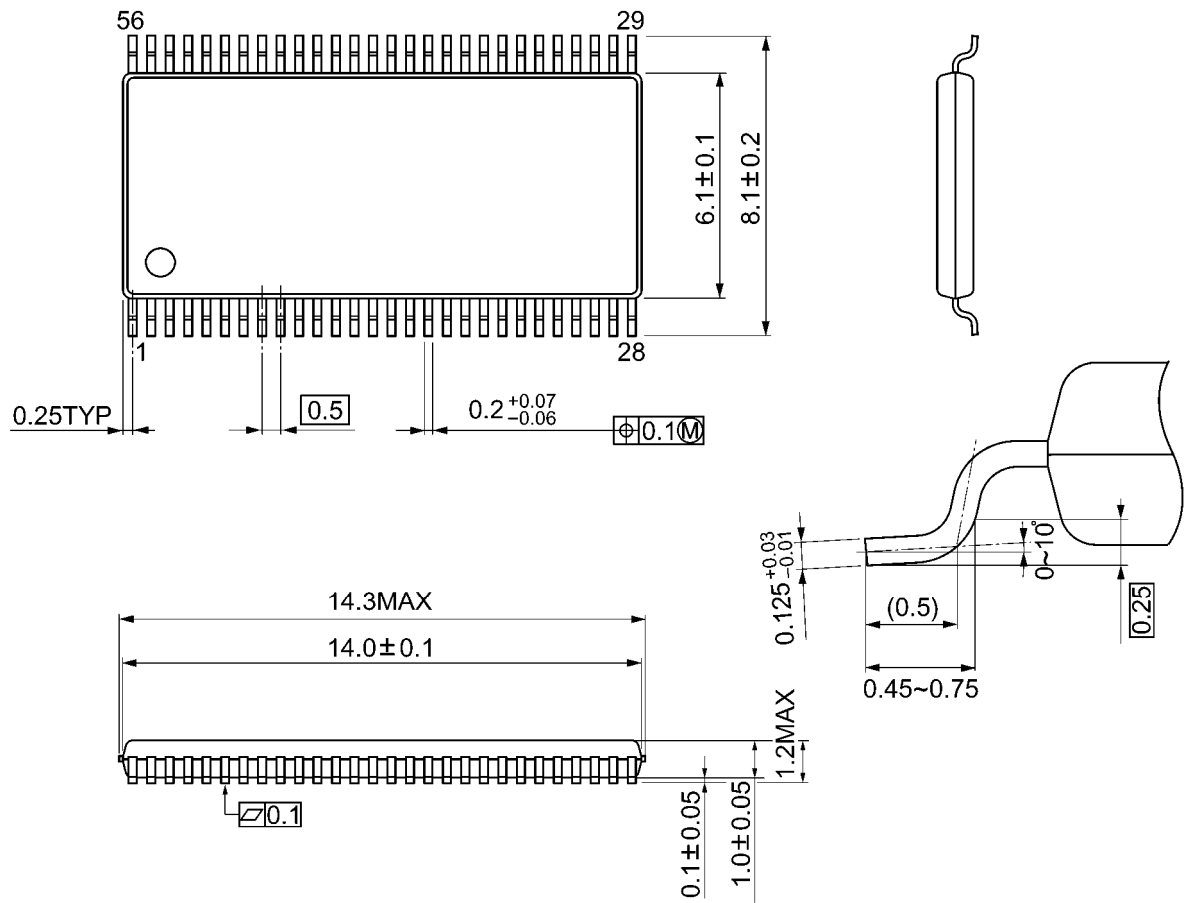
**Figure 5**  $t_{pLZ}$ ,  $t_{pHZ}$ ,  $t_{pZL}$ ,  $t_{pZH}$

Symbol	$V_{CC}$		
	$3.3 \pm 0.3 \text{ V}$	$2.5 \pm 0.2 \text{ V}$	$1.8 \text{ V}$
$V_{IH}$	$2.7 \text{ V}$	$V_{CC}$	$V_{CC}$
$V_M$	$1.5 \text{ V}$	$V_{CC}/2$	$V_{CC}/2$
$V_X$	$V_{OL} + 0.3 \text{ V}$	$V_{OL} + 0.15 \text{ V}$	$V_{OL} + 0.15 \text{ V}$
$V_Y$	$V_{OH} - 0.3 \text{ V}$	$V_{OH} - 0.15 \text{ V}$	$V_{OH} - 0.15 \text{ V}$

**Package Dimensions**

TSSOP56-P-0061-0.50A

Unit: mm



Weight: 0.25 g (typ.)

**RESTRICTIONS ON PRODUCT USE**

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