

## CMOS Logic ICs Selection Guide

### **Outline**

This application note describes how to select CMOS logic ICs. Specifically, it 1) lists the characteristics of each series of CMOS logic ICs; 2) shows the flow for selecting CMOS logic ICs based on system voltage and operating frequency; 3) describes input- and output-tolerant functions, voltage conversion techniques, and other topics.

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## 1. Selecting CMOS Logic ICs

Toshiba provides multiple series of CMOS logic ICs. Designed with different specifications and fabricated with different processes, each series has distinct characteristics. Each series is also available with different functions and in different packages.

This application note discusses which series is suitable for specific applications, based on system voltage, operating frequency, additional features, and other requirements.

Section 1.1, "Overview of the characteristics of each series," lists the electrical characteristics of each series as well as the available additional features and packages. The summary table allows you to compare the characteristics of all series simultaneously.

Section 1.2, "Flow for selecting CMOS logic ICs," describes how to narrow down applicable series, based on system voltage and operating frequency.

Section 1.3, "Electrical characteristics and additional features," provides detailed information about the characteristics and additional features shown in Section 1.1 and Section 1.2. It will help you to select the series that best meet your requirements.

Detailed specifications differ from IC to IC. Be sure to see the datasheets of individual ICs. For the functions of CMOS logic ICs, refer to the application note "Basics of CMOS Logic ICs."

### 1.1. Overview of the characteristics of each series

Toshiba provides the following series of CMOS logic ICs:

**Standard:** Supporting a wide operating voltage range (3 to 18 V), the Standard series is generally used at a system supply voltage of 6 V or higher.

**High-Speed:** The High-Speed series operates at higher frequency (at up to 40 MHz) than the Standard series and is generally used at a system supply voltage of 5 V.

**Advanced:** The Advanced series operates at even higher frequency (at up to 90 MHz) and provides high output current ( $\pm 24$  mA), making it suitable for use as transmission line drivers.

**Very-High-Speed:** The Very-High-Speed series combines high-frequency operation (at up to 90 MHz) and low-noise performance. Therefore, the Very-High-Speed series is widely used for high-speed applications.

**Low-Voltage and Very-Low-Voltage:** At 3 V, these series provide performance equivalent to or faster than the 5-V series (AC and VHC). The LCX series (operating at up to 120 MHz) and the VCX series (operating at up to 380 MHz) guarantee functional operation at 2.5 V and 1.8 V.

Table 1.1 summarizes the electrical characteristics and additional features of each series. This table shows the basic specifications for the system voltage, maximum operating frequency<sup>(a)</sup>, and drive capability at which each series is mainly used. It also shows the available additional features such as TTL-level inputs<sup>(b)</sup> and input- and output-tolerant functions. The check mark indicates that a given additional feature or package is available. Since detailed specifications differ from IC to IC, be sure to see the datasheets of individual ICs.

**Table 1.1 Product comparison**

| Series                               |   | Standard                                   | High-Speed   | Advanced                                   | Very-High-Speed <sup>*1</sup>                        | Low-Voltage                                 | Very-Low-Voltage  |   |
|--------------------------------------|---|--|--|--|--|---|---|---|
| Abbreviation                         |   | STD  | HC   | AC   | VHC  | LCX   | VCX   |   |
| Part number <sup>*2</sup>            |   | TC40xxB<br>TC45xxB                         | TC74HC<br>TC74HCT<br>74HC<br>74HCT                   | TC74AC<br>TC74ACT                          | TC74VHC<br>TC74VHCT<br>74VHC<br>74VHCT               | TC74LCX<br>74LCX                            | TC74VCX   |   |
| Key specifications                   | System voltage  | ≥ 6.0 V                                    | 5.0 V  | 5.0 V                                      | 5.0 V  | 1.65 to 3.6 V                               | 1.2 to 1.65 V   |   |
|                                      | Max. operating frequency <sup>*3</sup>                                      | Up to 10 MHz<br>at V <sub>DD</sub> = 5.0 V | Up to 40 MHz<br>at V <sub>CC</sub> = 4.5 V           | Up to 90 MHz<br>at V <sub>CC</sub> = 5.0 V | Up to 90 MHz<br>at V <sub>CC</sub> = 5.0 V           | Up to 120 MHz<br>at V <sub>CC</sub> = 3.0 V | Up to 380 MHz<br>at V <sub>CC</sub> = 3.0 V<br>Up to 30 MHz<br>at V <sub>CC</sub> = 1.5 V |   |
|                                      | Drive capability<br>(Output currents:<br>I <sub>OH</sub> /I <sub>OL</sub> ) | ±0.51 mA<br>at V <sub>DD</sub> = 5.0 V     | ±4 mA<br>at V <sub>CC</sub> = 4.5 V<br><sup>*4</sup> | ±24 mA<br>at V <sub>CC</sub> = 4.5 V       | ±8 mA<br>at V <sub>CC</sub> = 4.5 V<br><sup>*5</sup> | ±24 mA<br>at V <sub>CC</sub> = 3.0 V        | ±24 mA<br>at V <sub>CC</sub> = 3.0 V<br>±2 mA<br>at V <sub>CC</sub> = 1.5 V               |   |
| Features                             | TTL-level input   |  | —  | ✓  | ✓  | ✓   | ✓ <sup>*6</sup>   |   |
|                                      | Input-tolerant function   |  | —  | —  | —  | ✓   | ✓   |   |
|                                      | Output-tolerant function  |  | —  | —  | —  | ✓ <sup>*7</sup>                             | ✓   |   |
| Package                              | Hole-through  | DIP  | ✓  | ✓  | ✓  | ✓   | —   |   |
|                                      | Surface-mount   | SOIC                                       | —  | ✓  | —  | —   | —   | — |
|                                      |   | SOP  | ✓  | ✓  | ✓  | ✓   | ✓   | — |
|                                      |   | TSSOP                                      | ✓  | ✓  | ✓  | ✓   | ✓   | ✓ |
|                                      |   | US   | —  | —  | —  | ✓   | ✓   | ✓ |
| Equivalent series from other vendors |   | CD4000B<br>HEF4000<br>MC14000              | SN74HC<br>MM74HC<br>MC74HC                           | SN74AC<br>74AC<br>MC74AC                   | SN74AHC<br>74AHC<br>MC74VHC<br>SN74LV-A              | SN74LVC<br>74LVC<br>MC74LCX                 | SN74ALVC<br>SN74ALVT<br>74ALVC<br>74ALVT  |   |

\*1 The part numbers of some of the Very-High-Speed ICs contain the letter “9” or “V” preceding a function number like VHC9xxx and VHCVxxx. The letter “9” indicates a Schmitt trigger IC while the letter “V” represents a Schmitt trigger IC with an enhanced drive capability (±8 mA output current in the case of the VHC series and ±16 mA output current in the case of the VHCV series). For a description of the Schmitt trigger function, see Section 1.3.4.

\*2 The part numbers of some of the High-Speed, Advanced, and Very-High-Speed ICs contain the letter “T” preceding a function number. The letter “T” indicates an IC with a TTL-level input. For details, see Section 1.3.1.

\*3 The maximum operating frequencies shown above are the values calculated from the typical propagation delay times of typical ICs. For details, see Section 1.2.2.

\*4 High-Speed buffers provide a ±6 mA drive capability.

\*5 The VHCV series provides a ±16 mA drive capability.

\*6 The input signal meets the LVTTTL specification. For details, see Section 1.3.1.

\*7 The output-tolerant function is available with the VHCT and VHCV series.

\*a The maximum operating frequencies shown above are the values calculated from the typical propagation delay times of typical ICs (TC4001, 74HC244, TC74AC244, 74VHC244, 74LCX244, and TC74VCX244). Measured under Toshiba’s test conditions, they should be considered merely as a guide. For details, see Section 1.2.2.

\*b A CMOS logic IC with a TTL-level input provides a threshold voltage equivalent to that of a bipolar logic IC. For details, see Section 1.3.1.

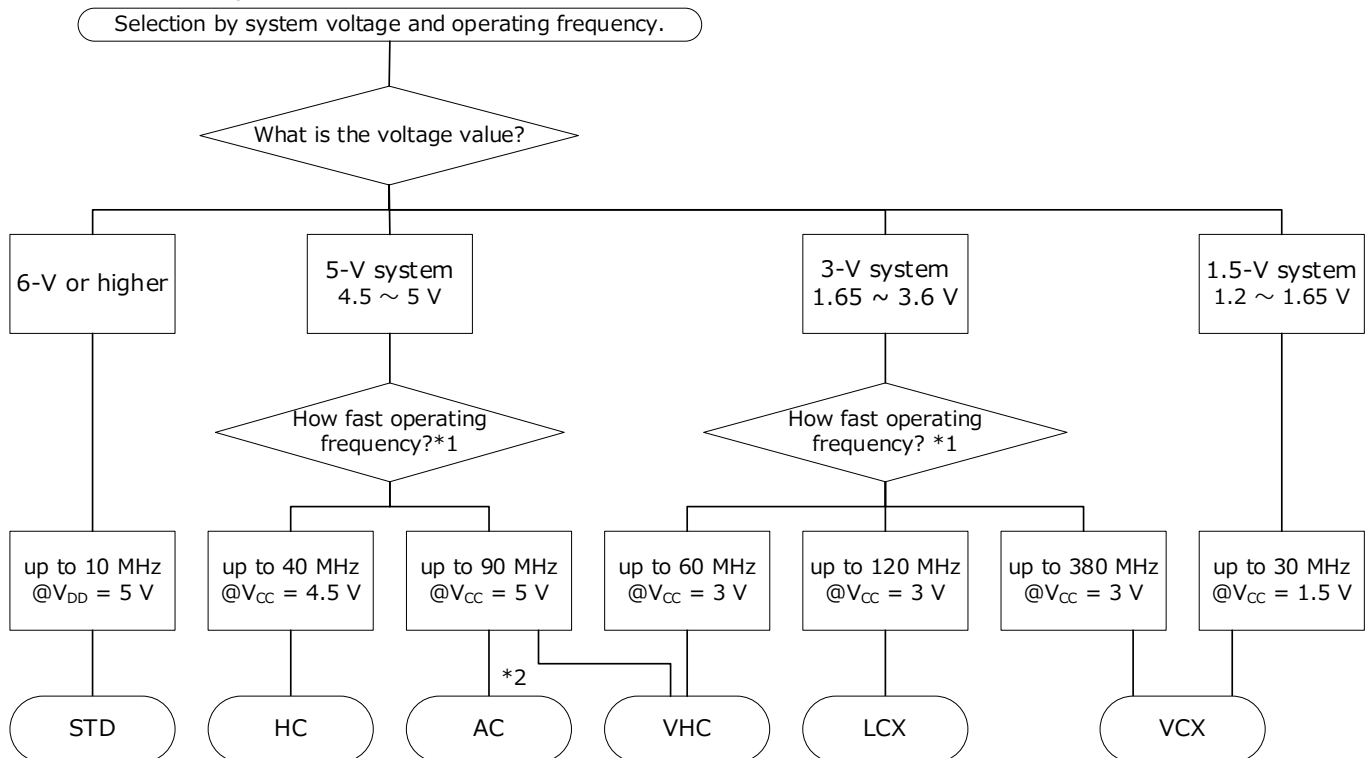
### 1.2. Flow for selecting CMOS logic ICs

Subsection 1.2.1 exemplifies the flow for selecting CMOS logic ICs based on system voltage and operating speed.

Subsection 1.2.2 shows how to calculate the maximum operating frequency when it is not shown in the IC datasheet.

#### 1.2.1. Flow for selecting CMOS logic ICs based on system voltage and operating frequency

Figure 1.1 shows the flow for selecting CMOS logic ICs based on system voltage and operating frequency. It allows you to narrow down the applicable series, firstly based on system voltage and then based on operating frequency.



**Figure 1.1 Flow for selecting CMOS logic ICs**

\*1 The maximum operating frequencies shown above are the values calculated from typical propagation delay times. For details, see Section 1.2.2.

\*2 As shown in Figure 1.4, the AC and VHC series exhibit little difference in the propagation delay time when driving an output load capacitance (C<sub>L</sub>) of 50 pF and therefore support an almost equal maximum operating frequency. For this reason, either the AC or VHC series can be selected according to the drive capability (output current) requirement.

**AC** (drive capability: ±24 mA): Select the AC series when a large drive capability is required to drive an input of a bipolar device or when an IC is directly connected to a system with a large capacitive load. However, if you use an IC with a large drive capability such as the AC series to drive a small capacitive load, the IC output tends to generate noise because of its fast rise and fall transitions. It is therefore important to select an IC with an appropriate drive capability.

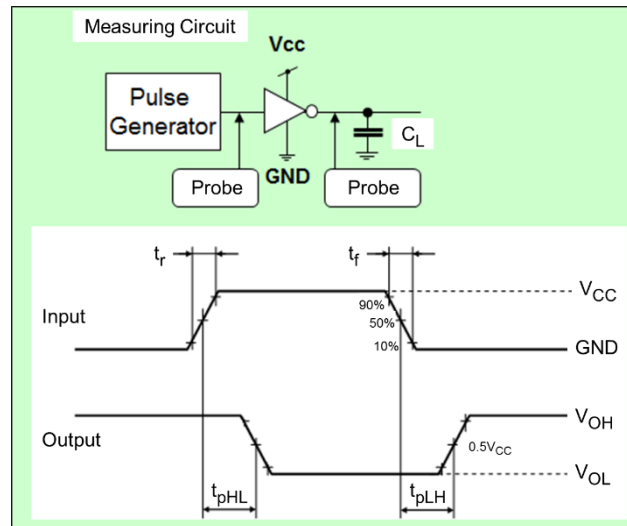
**VHC** (drive capability: ±8 mA): Select the VHC series when driving a CMOS device that does not require a large drive capability or when driving a small capacitive load. At a given capacitive load, the output of the VHC series rises and falls more slowly than that of the AC series and therefore generates less noise. Some ICs have a part number with the letter "V" following "VHC". These ICs provide ±16-mA output current. ([Link](#))

### 1.2.2. Maximum operating frequency

The maximum operating frequency values shown in Table 1.1 are the estimates calculated with the following equation from the propagation delay times ( $t_{pLH}$  and  $t_{pHL}$ ) shown in the datasheet.

$$\text{Maximum operating frequency} \approx 1/(t_{pLH} + t_{pHL})$$

All the ICs of a given series have an almost equal maximum operating frequency. The result of this calculation should be considered merely as an estimate under the conditions shown in the datasheet. Figure 1.2 shows a test circuit for the  $t_{pLH}$  and  $t_{pHL}$  of an IC and its propagation delay waveform.

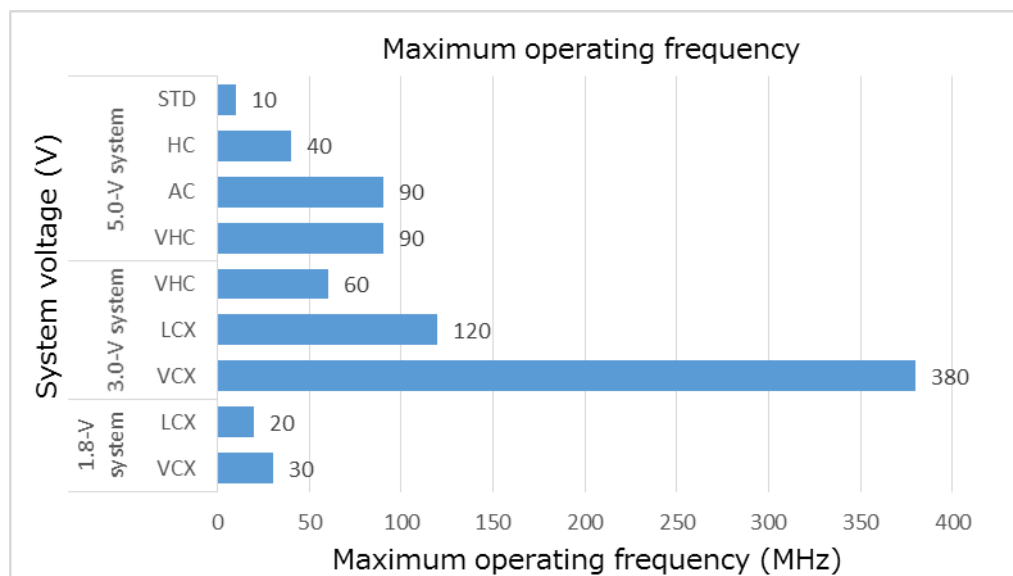


**Figure 1.2 Test circuit for propagation delay times and input and output waveforms**

Comparison of the maximum operating frequency at different voltages:

Figure 1.3 compares the maximum operating frequencies of the CMOS logic IC series at different system voltages.

Select an appropriate series according to a signal's operating frequency. A 5.0-V IC such as VHC series can be used to drive an IC in a lower-voltage domain (e.g., 3-V domain). In this case, however, the IC's maximum operating frequency becomes lower than the value shown in Figure 1.3.

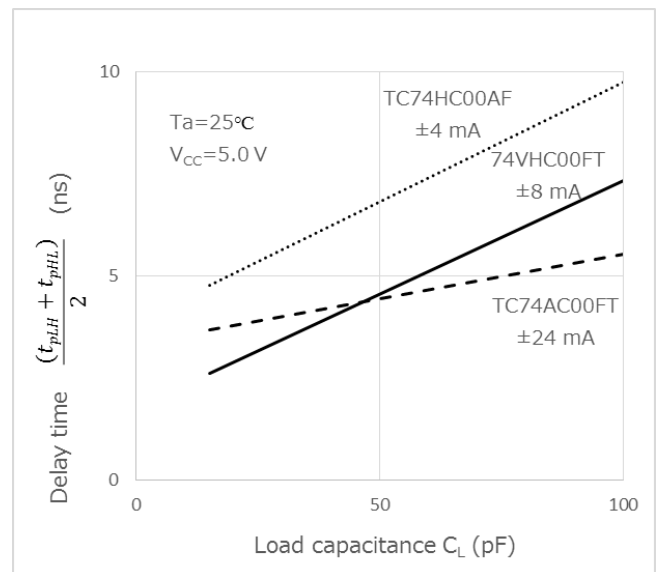


**Figure 1.3 Maximum operating frequency**

Propagation delay time vs. load capacitance:

Propagation delay times are dependent on load capacitance, as shown in Figure 1.4. As load capacitance ( $C_L$ ) increases, the time required to charge and discharge the load increases. Therefore, ICs with larger load capacitance exhibit longer propagation delay times.

Figure 1.4 shows the propagation delay time-vs-load capacitance characteristics of typical ICs of the AC, VHC, and HC series that are commonly used in 5-V systems. The output currents of these ICs are: TC74AC00 =  $\pm 24$  mA, 74VHC00 =  $\pm 8$  mA, and TC74HC00 =  $\pm 4$  mA. ICs with a larger output current ( $I_{OH}$  and  $I_{OL}$ ) are less dependent on load capacitance ( $C_L$ ). In other words, their propagation delay times increase less with an increase in  $C_L$ . Note, however, that ICs with a large output current exhibit short output rise and fall times and therefore generate larger switching noise, reflection, crosstalk, and electromagnetic interference (EMI). It is therefore important to select ICs with an appropriate output current.



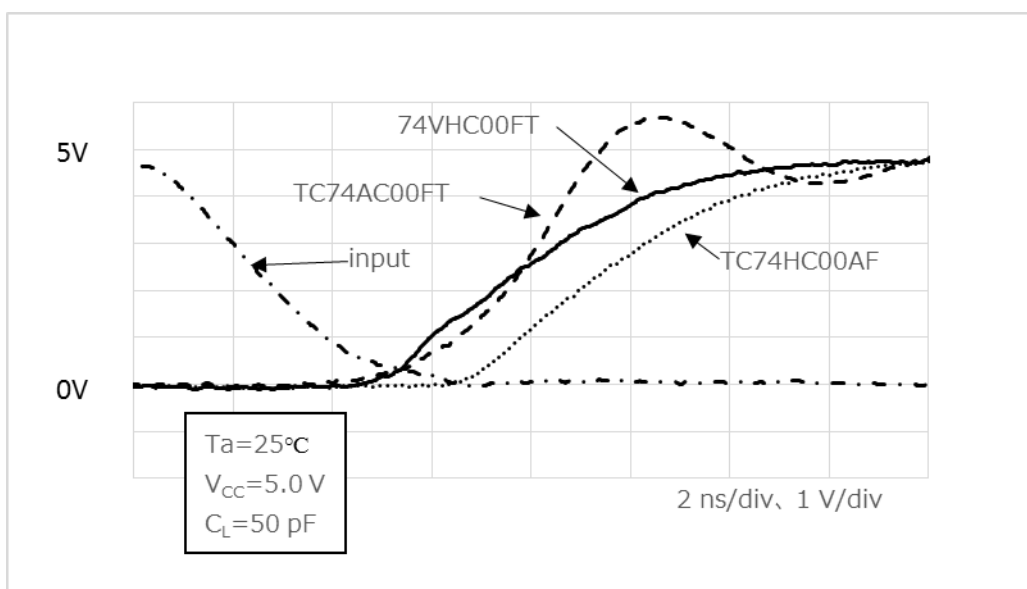
**Figure 1.4 Propagation delay time vs. load capacitance**

Input and output waveforms of the 5.0-V series (HC, AC, and VHC):

Figure 1.5 shows the input and output waveforms of the 5.0-V series.

It indicates that the AC and VHC series with a larger output current than the HC series exhibit a shorter rise time.

The 74VHC00FT and TC74AC00FT exhibit an almost identical output response. However, the TC74AC00FT has larger overshoot and undershoot because of the larger output current.



**Figure 1.5 Input transition and output response**

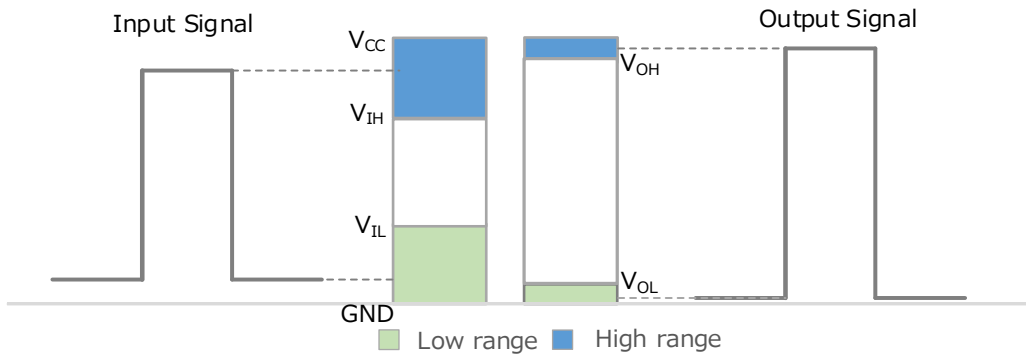


**1.3. Electrical characteristics and additional features**

This section discusses the electrical characteristics and additional features shown in Section 1.1 and Section 1.2 such as input and output voltage ranges (including a description of the TTL-level input), input-tolerant and output-tolerant functions, and Schmitt trigger input.

**1.3.1. Input and output voltage ranges**

High-level and low-level input voltages ( $V_{IH}$  and  $V_{IL}$ ) are specified for CMOS logic ICs.  $V_{IH}$  and  $V_{IL}$  are defined as the minimum and maximum voltage levels that are recognized as high and low logical levels, respectively. High-level and low-level output voltages ( $V_{OH}$  and  $V_{OL}$ ) are also specified for CMOS logic ICs that correspond to logic High and logic Low, respectively. This section represents the input and output voltage ranges as shown in Figure 1.6. The left-hand side indicates input voltage, and the right-hand side shows output voltage.



**Figure 1.6 Input and output voltage ranges**

$V_{IH}$ ,  $V_{IL}$ ,  $V_{OH}$ , and  $V_{OL}$  are specified in the datasheet as shown below. Figure 1.7 shows these characteristics of the 74VHC240.

**11.2. DC Characteristics (Unless otherwise specified,  $T_a = -40$  to  $85$  °C)**

| Characteristics           | Symbol   | Test Condition                | $V_{CC}$ (V)         | Min                 | Max                 | Unit |   |
|---------------------------|----------|-------------------------------|----------------------|---------------------|---------------------|------|---|
| High-level input voltage  | $V_{IH}$ | —                             | 2.0                  | 1.50                | —                   | V    |   |
|                           |          |                               | 3.0 to 5.5           | $V_{CC} \times 0.7$ | —                   | V    |   |
| Low-level input voltage   | $V_{IL}$ | —                             | 2.0                  | —                   | 0.50                | V    |   |
|                           |          |                               | 3.0 to 5.5           | —                   | $V_{CC} \times 0.3$ | V    |   |
| High-level output voltage | $V_{OH}$ | $V_{IN} = V_{IH}$ or $V_{IL}$ | $I_{OH} = -50 \mu A$ | 2.0                 | 1.9                 | —    | V |
|                           |          |                               |                      | 3.0                 | 2.9                 | —    | V |
|                           |          |                               | $I_{OH} = -4$ mA     | 4.5                 | 4.4                 | —    | V |
|                           |          |                               |                      | 3.0                 | 2.48                | —    | V |
| Low-level output voltage  | $V_{OL}$ | $V_{IN} = V_{IH}$ or $V_{IL}$ | $I_{OL} = 50 \mu A$  | 2.0                 | —                   | 0.1  | V |
|                           |          |                               |                      | 3.0                 | —                   | 0.1  | V |
|                           |          |                               | $I_{OL} = 4$ mA      | 4.5                 | —                   | 0.1  | V |
|                           |          |                               |                      | 3.0                 | —                   | 0.44 | V |
|                           |          |                               | $I_{OL} = 8$ mA      | 4.5                 | —                   | 0.44 | V |

**Figure 1.7 Input voltage and output voltage specifications in a datasheet**

When  $V_{CC}=4.5$  V, the input is recognized as being at logic High when it is 3.15 V or higher.

When  $V_{CC}=4.5$  V, the input is recognized as being at logic Low when it is 1.35 V or lower.

When  $V_{CC}=4.5$  V, the 8-mA output provides 3.80 V or higher when it is at logic High.

When  $V_{CC}=4.5$  V, the 8-mA output provides 0.44 V or lower when it is at logic Low.

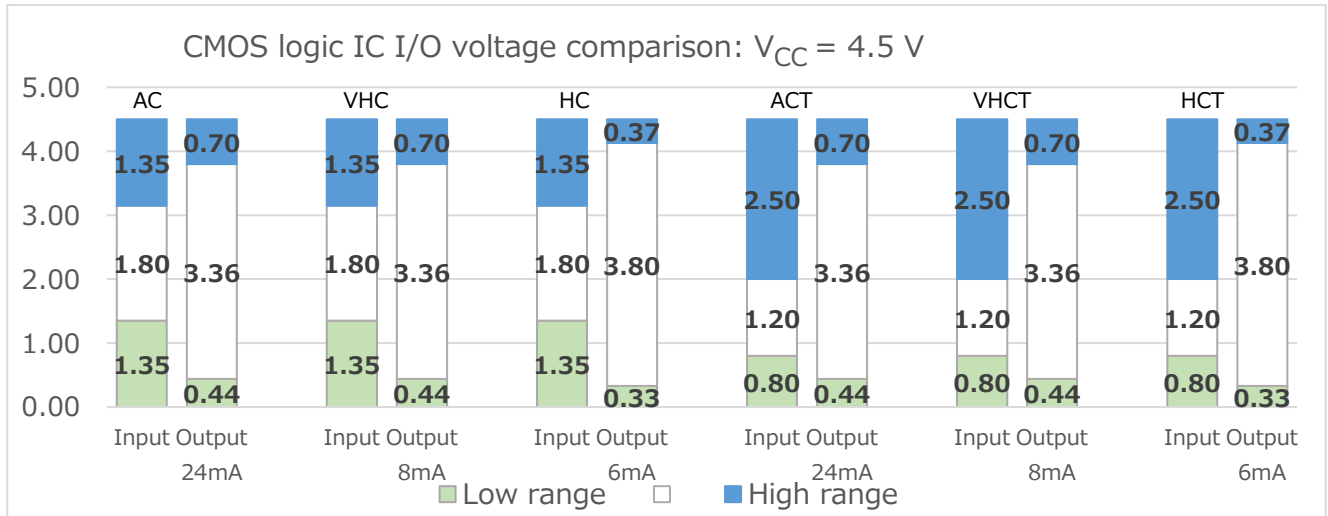
**TTL-level input:**

A CMOS logic IC with a TTL-level input provides an input threshold voltage equivalent to that of a bipolar logic IC. Bipolar logic ICs provide a maximum low-level input voltage ( $V_{IL}$ ) of 0.8 V and a minimum high-level input voltage ( $V_{IH}$ ) of 2.0 V. These are called TTL input logic levels. The series ending with the letter "T" such as (HCT, ACT, VHCT) have a TTL-level input. There is also a 3-V interface standard called LVTTTL (JEITA ED-5001A) that standardizes the LVTTTL threshold voltages as is the case with TTL. The LCX and VCX series satisfy the LVTTTL requirements.

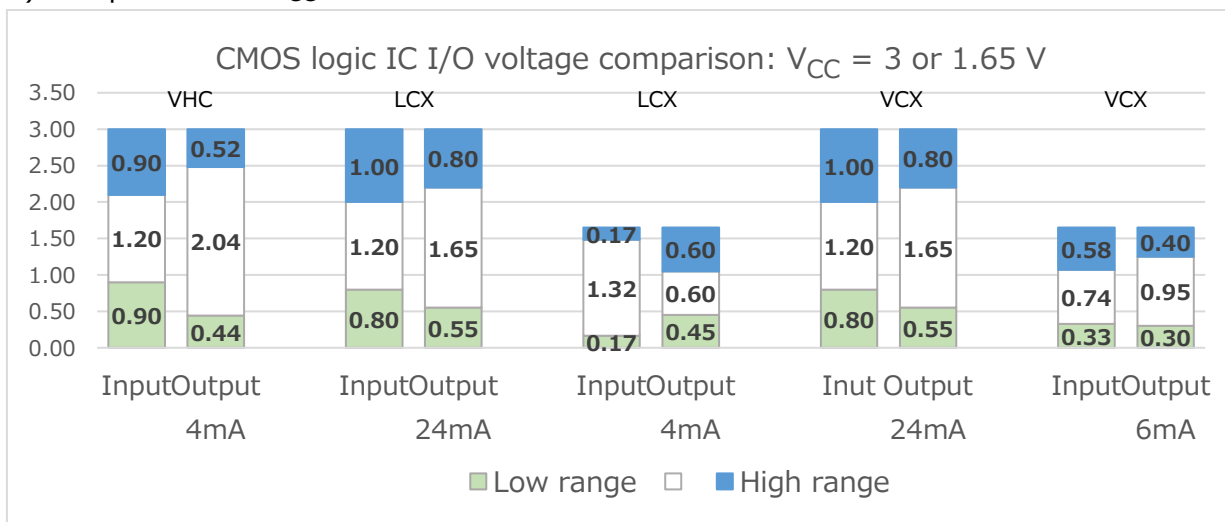
Figure 1.8 shows the input voltage ( $V_{IH}$  and  $V_{IL}$ ) and output voltage ( $V_{OH}$  and  $V_{OL}$ ) specifications of each series.

The lower the output current, the larger the difference between  $V_{OH}$  and  $V_{OL}$ .

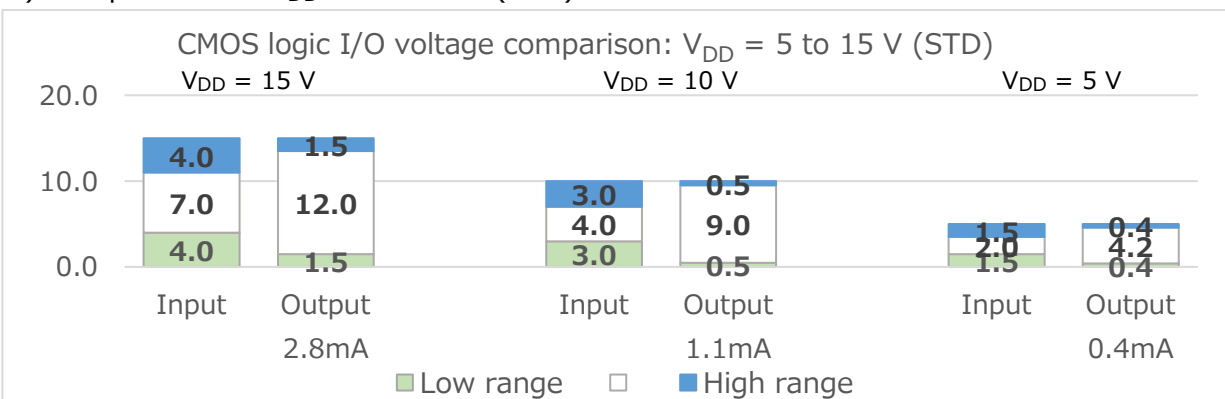
### 1) Comparisons at $V_{CC} = 4.5\text{ V}$



### 2) Comparisons at $V_{CC} = 3\text{ V}$ or $1.65\text{ V}$



### 3) Comparisons at $V_{DD} = 5\text{ to }15\text{ V (STD)}$



Note: The input and output voltage ranges shown above are the worst-case values of typical ICs (TC4001, 74HC244, TC74AC244, 74VHC244, 74LCX244, and TC74VCX244) in the temperature range of  $-40\text{ to }85^\circ\text{C}$ .

**Figure 1.8 Input and output voltage ranges of each series**

### 1.3.2. Input-tolerant function (input power-down protection)

The input-tolerant function is designed to prevent current from flowing from an input to the power supply when the input voltage is set higher than the power supply voltage ( $V_{CC}$ ) or when  $V_{CC} = 0$  V. The allowable input voltage specification is shown in the Operating Ranges of the datasheet. When the input voltage range is specified as 0 to  $V_{CC}$ , voltage higher than  $V_{CC}$  must not be applied because the circuit has a diode to  $V_{CC}$  (i.e., no input-tolerant function).

The input voltage range of the VHC, VHCT, VHC9, VHCV, and LCX series is specified as 0 to 5.5 V (with the input-tolerant function); thus, up to 5.5 V can be applied to the input regardless of the power supply voltage (Figure 1.9).

The input voltage range of the VCX series is specified as 0 to 3.6 V (with the input-tolerant function); thus, up to 3.6 V can be applied to the input regardless of the power supply voltage.

The input voltage range of the STD, AC, ACT, HC, and HCT series is specified as 0 to  $V_{CC}$ . This means these series do not have an input-tolerant function. (The input-tolerant function available with a given series might differ from IC to IC. Be sure to see the datasheets of individual ICs.)

### 1.3.3. Output-tolerant function (output power-down protection)

The output-tolerant function is designed to prevent current from flowing from an output to the power supply when the output assumes the high-impedance state or when power supply ( $V_{CC}$ ) = 0 V. The allowable output voltage specification is shown in the Operating Ranges of the datasheet. When the output voltage range is specified as 0 to  $V_{CC}$ , voltage higher than  $V_{CC}$  must not be applied because the circuit has a diode to  $V_{CC}$  (i.e., no output-tolerant function).

The output voltage range of the VHCT, VHCV, and LCX series is specified as 0 to 5.5 V when the output is in the high-impedance state (since it has an output-tolerant function); thus, up to 5.5 V can be applied to the output regardless of the power supply voltage (Figure 1.9).

The output voltage range of the VCX series is specified as 0 to 3.6 V when the output is in the high-impedance state (since it has an output-tolerant function); thus up to 3.6 V can be applied to the input regardless of the power supply voltage.

The output voltage range of the STD, AC, ACT, HC, HCT, VHC, VHC9 series is specified as 0 to  $V_{CC}$ . This means these series do not have an output-tolerant function. (The output-tolerant function available with a given series might differ from IC to IC. Be sure to see the datasheets of individual ICs.)

|                                     | With an input-tolerant function   | Without an input-tolerant function |
|-------------------------------------|---|------------------------------------|
| With an output-tolerant function    | <p>VHCT, VHCV, LCX, VCX<br/>(Up to 3.6 V can be applied to the input and output of the VCX series.)</p> |                                    |
| Without an output-tolerant function | <p>VHC, VHC9</p>  |                                    |

**Figure 1.9 Maximum voltages tolerated by input and output pins**

Table 1.2 summarizes the presence or absence of the input- and output-tolerant functions and the allowable input and output voltage ranges for each series. The input- and output-tolerance functions available with a given series might differ from IC to IC. Be sure to see the datasheets of individual ICs.

**Table 1.2 Input- and output-tolerant functions**

| Tolerant Function |                             | Both input and output      | Only input                           | Neither input nor output             |
|-------------------|-----------------------------|----------------------------|--------------------------------------|--------------------------------------|
| Series            |                             | VHCT, VHCV, LCX, VCX,      | VHC, VHC9                            | STD, AC, ACT, HC, HCT                |
| Input voltage     | During operation            | 0 to 5.5 V<br>(VCX: 3.6 V) | 0 to 5.5 V                           | 0 to $V_{CC}$                        |
|                   | When supply voltage = 0 V   | 0 to 5.5 V<br>(VCX: 3.6 V) | 0 to 5.5 V                           | 0 V<br>(Voltage cannot be supplied.) |
| Output voltage    | When the output is enabled  | 0 to $V_{CC}$              | 0 to $V_{CC}$                        | 0 to $V_{CC}$                        |
|                   | When the output is disabled | 0 to 5.5 V<br>(VCX: 3.6 V) | 0 to $V_{CC}$                        | 0 to $V_{CC}$                        |
|                   | When supply voltage = 0 V   | 0 to 5.5 V<br>(VCX: 3.6 V) | 0 V<br>(Voltage cannot be supplied.) | 0 V<br>(Voltage cannot be supplied.) |

### 1.3.4. Schmitt trigger input

A Schmitt trigger input has two threshold voltages, the difference of which is called a hysteresis band. Figure 1.10 shows the input and output waveforms of a Schmitt trigger buffer with an input threshold hysteresis. Figure 1.11 shows its  $V_{OUT}$ - $V_{IN}$  characteristics.

In the case of an IC with hysteresis, the positive-going threshold voltage ( $V_P$ ) differs from the negative-going threshold voltage ( $V_N$ ). For a slowly rising or falling input, an input threshold hysteresis ( $V_H$ ) helps to stabilize the output. Even in the presence of input noise or power supply or ground bounce due to noise, an IC does not provide a false output unless the noise or bounce exceeds the hysteresis width.

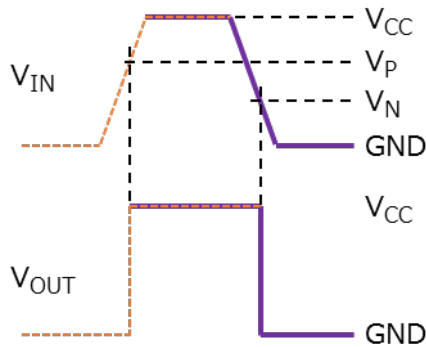


Figure 1.10 Input and output waveforms

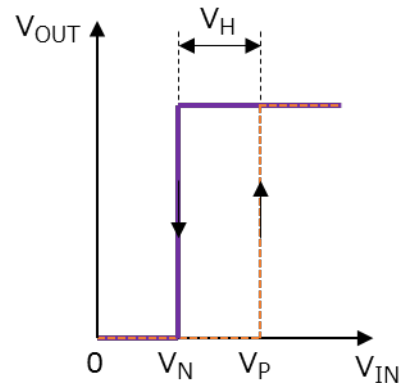


Figure 1.11  $V_{OUT}$  vs.  $V_{IN}$

Typical ICs with input threshold hysteresis include a Schmitt trigger inverter (14) and a two-input Schmitt trigger NAND gate (132). (The numbers enclosed within parentheses are function numbers.) In addition, Toshiba's VHC9 and VHCV series have Schmitt trigger inputs.

In addition, the VHC and VHCT series provide ICs with simplified Schmitt trigger characteristics (except functions 14 and 132). For these ICs,  $V_P$  and  $V_N$  are not specified. If ICs with a prescribed hysteresis are required, use Schmitt trigger ICs.

### 1.3.5. Voltage conversion techniques

CMOS logic ICs are sometimes used to interface between ICs in different voltage domains. This subsection describes different voltage conversion techniques. Table 1.3 summarizes several techniques for unidirectional step-up and step-down voltage conversion as well as bidirectional step-up/step-down voltage conversion. Each technique is explained in 1) to 4) below. Figures 1.12 to 1.15 depict each technique.

**Table 1.3 Voltage conversion techniques**

| Voltage Conversion | Signal Direction | Method  | Description  |
|--------------------|------------------|---|--|
| Step-down          | Unidirectional   | 1) Input-tolerant function                              | Since the input pin has no diode to $V_{CC}$ , it tolerates voltage of up to the specified limit.  |
|                    |                  | 2) Open-drain output                                    | The open-drain output allows its voltage to be pulled up to the supply voltage to which a pull-up resistor is connected. Since the output rise time is affected by the pull-up resistor, it differs from the output fall time. |
| Step-up            | Unidirectional   | 2) Open-drain output (with an output-tolerant function) | The open-drain output allows its voltage to be pulled up to the supply voltage to which a pull-up resistor is connected. Since the output rise time is affected by the pull-up resistor, it differs from the output fall time. |
|                    |                  | 3) Level-shifting bus buffers                           | Dual-supply bus buffer ICs that incorporate a level-shifting circuit.  |
| Step-up/step-down  | Bidirectional    | 3) Level-shifting bus buffers                           | Dual-supply bus buffer ICs that incorporate a level-shifting circuit.  |
|                    |                  | 4) Level-shifting bus switches                          | Dual-supply bus switch ICs that perform level shifting via an external pull-up resistor. Since the output rise time is affected by the pull-up resistor, it differs from the output fall time.                                 |

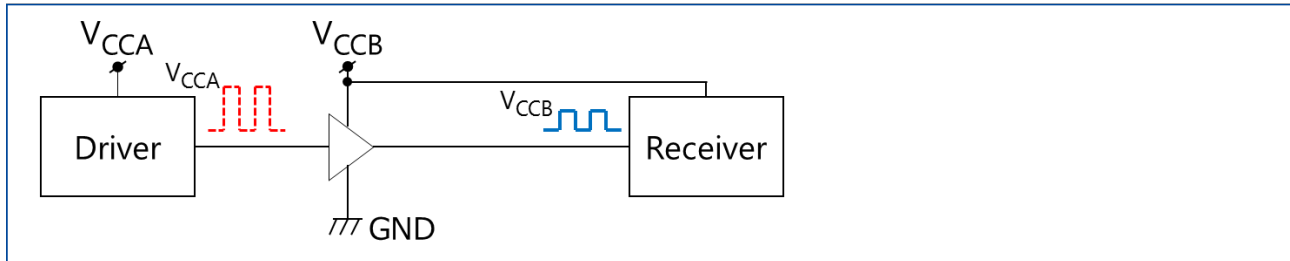
### 1) Input-tolerant function (unidirectional step-down voltage conversion)

The input-tolerant function (having no diode from the input pin to  $V_{CC}$ ) allows level shifting from a higher voltage to a lower voltage. For example, the input-tolerant function allows up to the maximum input voltage to be applied to an input without drawing extra current when  $V_{CC} = 0$  V. Additionally, it provides easy level shifting without increasing the propagation delay.

Product selection options:

The VHC and LCX series can be used for conversion from 5 V to 3 V.

The VCX series can be used for conversion from 3 V to 1.2 V.



**Figure 1.12 Step-down voltage conversion using an input-tolerant function**

### 2) Open-drain output (unidirectional step-up and step-down voltage conversion)

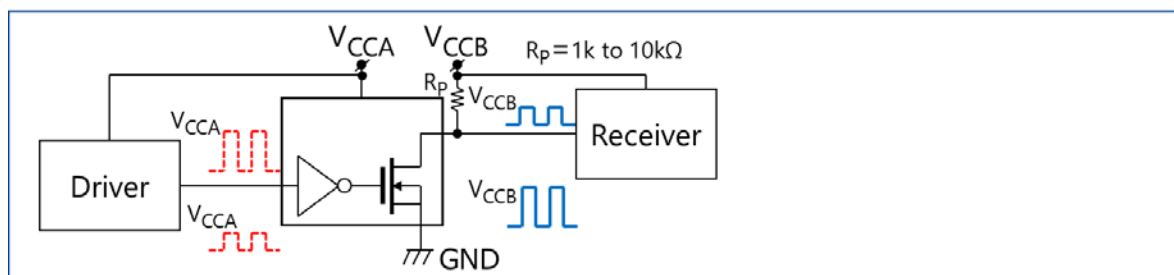
Connect one end of a pull-up resistor to the output of an open-drain IC and the other end of the pull-up resistor to an arbitrary power supply. This allows conversion from the output voltage to an arbitrary power supply voltage. However, when the output of an IC is pulled up to a supply voltage higher than its own power supply (when  $V_{CCA} < V_{CCB}$  in Figure 1.13), it is necessary to use an IC with an output-tolerant function so that current does not flow from  $V_{CCB}$  to  $V_{CCA}$ .

In addition, an appropriate pull-up resistor should be selected since steady-state current flows through the pull-up resistor. The IC draws more current when it drives a logic Low than when it drives a logic High. Since the output rise time is affected by the pull-up resistor, it differs from the output fall time.

Product selection options:

Open-drain ICs (03, 05, and 07) can be used for step-down voltage conversion.

The open-drain ICs with an output-tolerant function (05 and 07) of the VHCV and LCX series can be used for step-up voltage conversion.



**Figure 1.13 Step-up and step-down voltage conversion using an open-drain IC**

**3) Dual-supply level-shifting bus buffers (unidirectional step-up voltage conversion and bidirectional step-up/step-down voltage conversion)**

Dual-supply bus buffer ICs that incorporate a level-shifting circuit.

Some bus buffers allow only step-up (unidirectional) voltage conversion while others allow both step-up and step-down (bidirectional) voltage conversion. The bus buffers for step-up/step-down (bidirectional) voltage conversion allow the signal direction to be changed via the DIR input pin.

Some bus buffers require that  $V_{CCA}$  be lower than  $V_{CCB}$ . See the datasheets of individual ICs.

Level-shifting bus buffers are faster and draw less current than using open-drain ICs for level shifting.

Product selection options:

The TC7SP3125 (with the OE pin) can be used for step-up voltage conversion (from a  $V_{CCA}$  of 1.1 to 2.7 V to a  $V_{CCB}$  of 1.65 to 3.6 V).

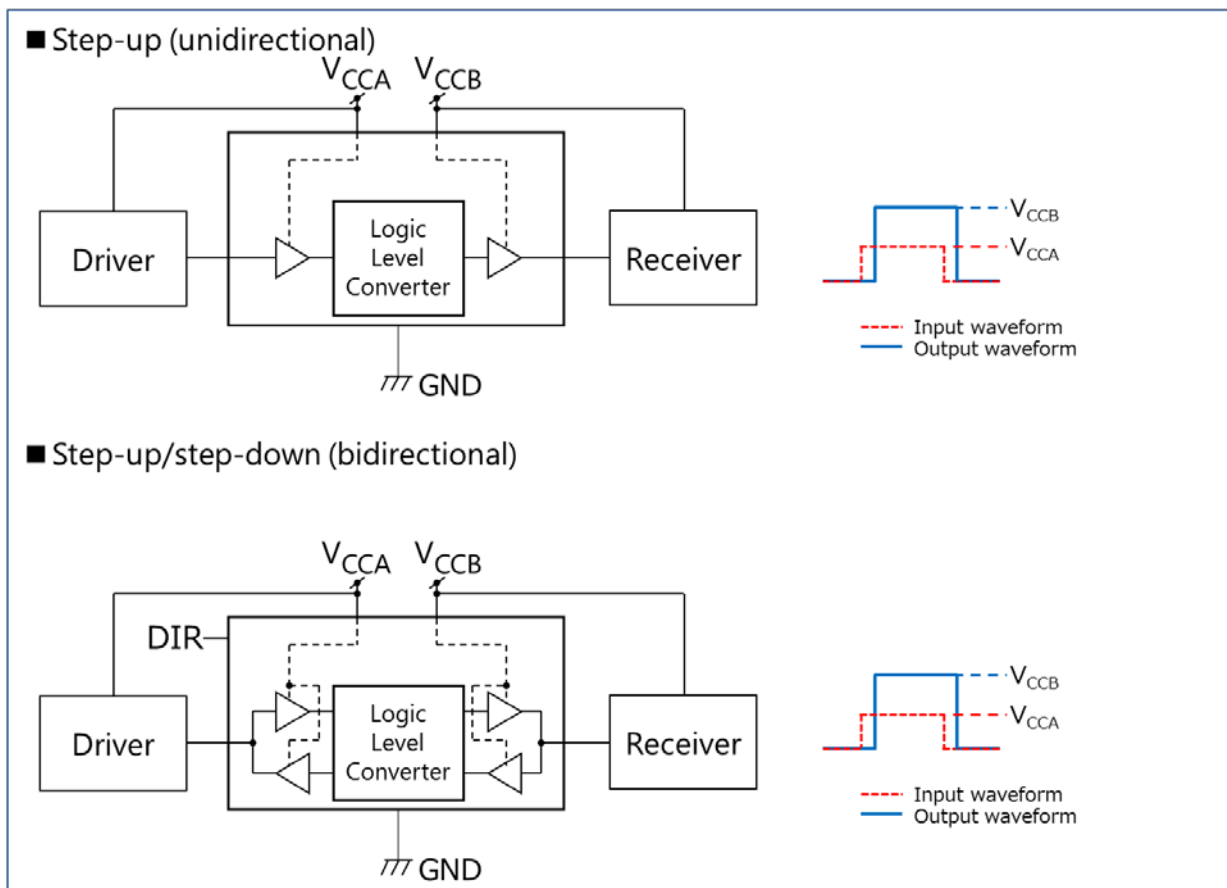
The TC7SPN3125 also features low noise.

The low-noise TC7SPN334 (without the OE pin) can be used for step-up voltage conversion (from a  $V_{CCA}$  of 1.1 to 2.7 V to a  $V_{CCB}$  of  $V_{CCA}$  to 3.6 V).

The TC74LCX163245 allows step-up/step-down voltage conversion from a  $V_{CCA}$  of 4.5 to 5.5 V to a  $V_{CCB}$  of 2.3 to 3.6 V. The TC74LCX164245 allows step-up/step-down voltage conversion from a  $V_{CCA}$  of 2.3 to 3.6 V to a  $V_{CCB}$  of 4.5 to 5.5 V.

The TC74VCX163245 allows step-up/step-down voltage conversion from a  $V_{CCA}$  of 2.3 to 3.6 V to a  $V_{CCB}$  of 1.65 to 2.7 V. The TC74VCX164245 allows step-up/step-down voltage conversion from a  $V_{CCA}$  of 1.65 to 2.7 V to a  $V_{CCB}$  of 2.3 to 3.6 V.

The TC7MP3125 allows step-up/step-down voltage conversion from a  $V_{CCA}$  of 1.1 to 2.7 V to a  $V_{CCB}$  of 1.65 to 3.6 V. The TC7MPN3125 also features low noise.



**Figure 1.14 Step-up/step-down voltage conversion using a dual-supply level-shifting bus buffer**



**4) Dual-supply level-shifting bus switches (bidirectional step-up/step-down voltage conversion)**

Dual-supply bus switch ICs that perform level shifting via an external pull-up resistor.

These bus switches can be used to interface between two voltage domains without the need for controlling the signal direction (DIR).

The bus switches are suitable for I<sup>2</sup>C applications. Single-pole single-throw (SPST) and single-pole double-throw (SPDT) bus switches are available. Level-shifting bus switches require that  $V_{CCA}$  be lower than  $V_{CCB}$ .

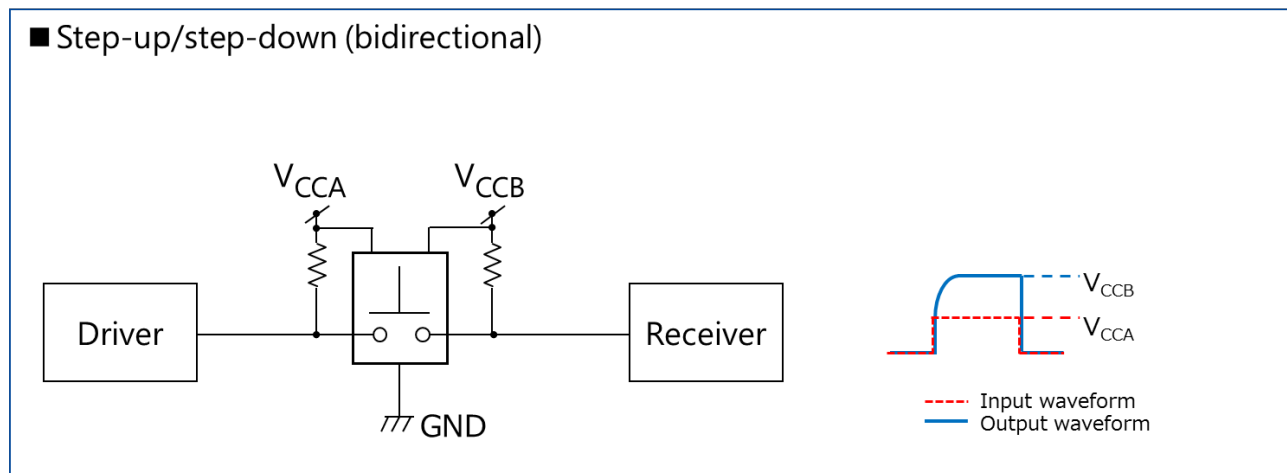
An appropriate pull-up resistor should be selected since steady-state current flows through the pull-up resistor. The IC draws more current when it drives a logic Low than when it drives a logic High. Since the output rise time is affected by the pull-up resistor, it differs from the output fall time.

Product selection options:

Step-up/step-down voltage conversion between a  $V_{CCA}$  of 1.65 to 5.0 V and a  $V_{CCB}$  of 2.3 to 5.5 V

As SPST bus switches, the TC7SPB9306 with the active-High OE input and the TC7SPB9307 with the active-Low /OE input are available. Multi-bit bus switches are also available. The TC7WPBxxxx are 2-bit bus switches, the TC7QPBxxxx are 4-bit bus switches, and the TC7MPB are 8-bit bus switches.

As SPDT bus switches, the TC7MPB9326 with the active-High OE input and the TC7MPB9327 with the active-Low /OE input are available. Both the TC7MPB9326 and TC7MPB9327 are two-bit bus switches.



**Figure 1.15 Step-up/step-down voltage conversion using a dual-supply level-shifting bus switch**

## 1.4. Product lineup

For the product lineup, see the Semiconductor General Catalog at:

<https://toshiba.semicon-storage.com/ap-en/semiconductor/knowledge/product-list.html>

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