

***3.3-V to 2.5-V Translation  
With Texas Instruments  
Crossbar Technology***

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## Introduction

The Texas Instruments (TI™) crossbar-technology (CBT) family is known for its multipurpose use in the design arena. It is used in almost every personal computer, server, workstation, and telecom application in the industry. CBT is an easy and low-cost solution for systems that require:

- Bus isolation
- Bus swapping in a multiprocessor/memory environment
- Live insertion
- 5-V to 3.3-V translation
- 3.3-V to 2.5-V translation

Translation from 3.3 V to 2.5 V is accomplished easily; however, reliable translation from 2.5 V to 3.3 V cannot be achieved with the existing CBT family because there is no noise margin for the high-state switching.

### 2.5-V and 3.3-V Switching Standards

Figure 1 shows the 3.3-V and 2.5-V switching thresholds.

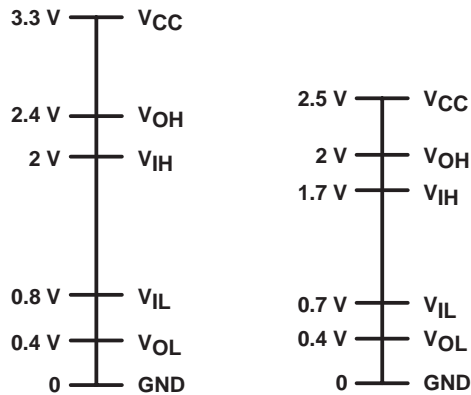


Figure 1. 3.3-V and 2.5-V V<sub>CC</sub> Thresholds

#### 3.3-V to 2.5-V Translation

Figure 1 shows there is enough noise margin (300 mV for low state and 700 mV for high state) to establish reliable translation from 3.3-V logic to 2.5-V logic. This is always valid, but one must ensure that the input clamping diode of the 2.5-V device is not forward biased. V<sub>IH</sub> should not exceed V<sub>CC</sub> (2.5-V logic) + 0.3 V.

#### 2.5-V to 3.3-V Translation

Figure 1 shows a 400-mV noise margin for the low-state translation, but zero noise margin for the high state, and therefore, translation from 2.5-V to 3.3-V devices cannot be achieved without additional consideration.

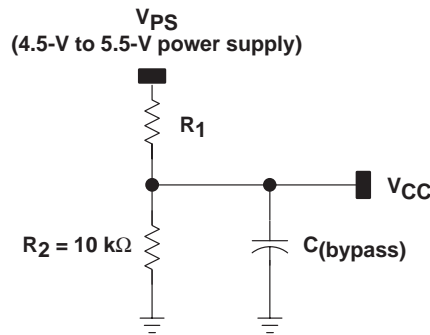
## Translating With CBT

A CBT switch is a simple NMOS transistor that acts like a resistor when it is on. Its impedance varies with the amount of current flowing from its drain to its source. A single 3.3-V power supply connected to  $V_{CC}$  is not enough to provide sufficient translation since  $V_{OH}$  can vary, depending on the input current ( $I_I$ ) through the switch. The higher  $I_I$  is, the lower the output logic level  $V_{OH}$  is. A higher 2.5-V device  $V_{CC}$  is required to maintain the minimum  $V_{OH}$ . The following tables show the required 2.5-V device  $V_{CC}$  to maintain a 2-V and 2.4-V  $V_{OH}$ .

$V_{IN} = 3.3\text{ V}, V_{OH(MIN)} = 2\text{ V}$	
$I_I$ THROUGH THE SWITCH	REQUIRED $V_{CC}$
1 $\mu\text{A}$	2.75 V
100 $\mu\text{A}$	3 V
1 mA	3.1 V
15 mA	3.5 V
30 mA	3.7 V

$V_{IN} = 3.3\text{ V}, V_{OH(MIN)} = 2.4\text{ V}$	
$I_I$ THROUGH THE SWITCH	REQUIRED $V_{CC}$
1 $\mu\text{A}$	3.1 V
100 $\mu\text{A}$	3.4 V
1 mA	3.6 V
15 mA	4 V
30 mA	4.2 V

To achieve a good supply voltage to the  $V_{CC}$  pin and still be able to modify it based on the input current requirement, a voltage divider should be used to derive the required voltage, as shown in Figure 2. The recommended value of  $R_2$  is 10 k $\Omega$ .  $C_{(bypass)}$  is the bypass capacitor (recommended value ranges from 0.1 to 0.01  $\mu\text{F}$  and should be as close as possible to the  $V_{CC}$  pin of the CBT device). The value of  $R_1$  is determined from the power-supply voltage, the input current, and the  $V_{OH}$  requirement.



Note:  $C_{(bypass)} = 0.1$  to  $0.01\ \mu\text{F}$

**Figure 2. Divider Network**

Choosing the correct resistor size ( $R_1$ ) depends on three factors:

- Power-supply voltage level ( $V_{PS}$ )
- Chip power-supply voltage needed ( $V_{CC}$ )
- $V_{OH}$  level of the switch

R<sub>1</sub> can be calculated using the generalized formula:

$$R_1 = V_{R1}/I_{R1} \tag{1}$$

Where:

$$\begin{aligned} V_{R1} &= V_{PS} - V_{CC} \\ I_{R1} &= I_{R2} + I_{CC} \\ I_{R2} &= V_{CC}/R_2 \\ I_{CC} &= 100 \mu A \\ R_2 &= 10 k\Omega \end{aligned}$$

The generalized formula for R<sub>1</sub> can be expanded, by substitution, to:

$$R_1 = (V_{PS} - V_{CC})/[(V_{CC}/10 k\Omega) + 100 \mu A] \tag{2}$$

The following tables show the range of R<sub>1</sub> based on a 5-V supply voltage (V<sub>PS</sub>), 3.3-V input signal (V<sub>IH</sub>), 2-V and 2.4-V V<sub>OH</sub> level with up to 30-mA I<sub>(I)</sub> through the switch. These tables allow the designer to choose the correct resistor for the design, based on design requirements.

V <sub>IN</sub> = 3.3 V, V <sub>OH(MIN)</sub> = 2 V, I <sub>CC</sub> = 100 μA				
I <sub>I</sub> THROUGH THE SWITCH	REQUIRED V <sub>CC</sub> (V)	R <sub>1</sub> AT V <sub>PS</sub> = 4.5 V (kΩ)	R <sub>1</sub> AT V <sub>PS</sub> = 5 V (kΩ)	R <sub>1</sub> AT V <sub>PS</sub> = 5.5 V (kΩ)
1 μA	2.75	4.64	6.04	7.32
100 μA	3	3.74	4.99	6.19
1 mA	3.1	3.4	4.64	5.9
15 mA	3.5	2.21	3.32	4.42
30 mA	3.7	1.69	2.74	3.83

V <sub>IN</sub> = 3.3 V, V <sub>OH(MIN)</sub> = 2.4 V, I <sub>CC</sub> = 100 μA				
I <sub>I</sub> THROUGH THE SWITCH	REQUIRED V <sub>CC</sub> (V)	R <sub>1</sub> AT V <sub>PS</sub> = 4.5 V (kΩ)	R <sub>1</sub> AT V <sub>PS</sub> = 5 V (kΩ)	R <sub>1</sub> AT V <sub>PS</sub> = 5.5 V (kΩ)
1 μA	3.1	3.4	4.64	5.9
100 μA	3.4	2.49	3.65	4.75
1 mA	3.6	1.96	3.01	4.12
15 mA	4	1	2	3.01
30 mA	4.2	0.576	1.54	2.49

## Conclusion

TI's CBT family is versatile, not only in the 5-V or the 3.3-V environment, but also in the 2.5-V arena, using a single 5-V power supply to generate required voltage for its V<sub>CC</sub> pin. This family functions reliably as long as the above conditions are met.

## Acknowledgment

This application report was written by Ramzi Ammar, SLL Applications, Texas Instruments.

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