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

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Contents

List of Illustrations

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.

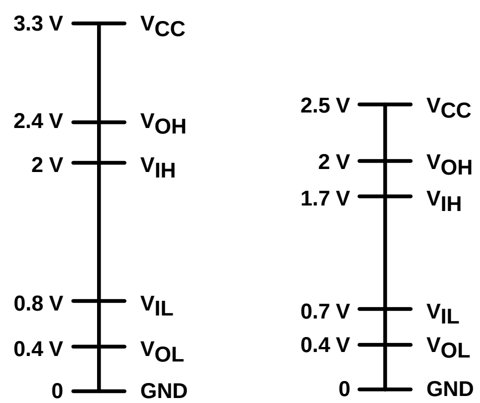

Figure 1. 3.3-V and 2.5-V V_{CC} Thresholds

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_{IH} should not exceed V_{CC} (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.

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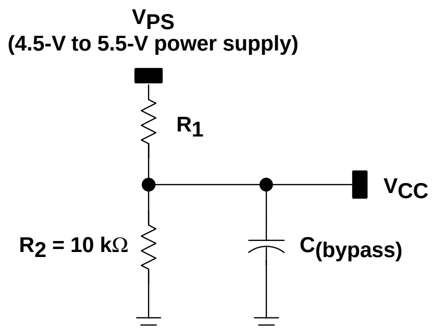
Translating With CBT

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

V_{IN} = 3.3 V, $V_{OH(MIN)}$ = 2.4 V	
I_I THROUGH THE SWITCH	REQUIRED V_{CC}
1 µA	3.1 V
100 µA	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 kΩ. $C_{(bypass)}$ is the bypass capacitor (recommended value ranges from 0.1 to 0.01 µF 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 µF

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_1 can be calculated using the generalized formula:

$$R_1 = V_{R1}/I_{R1} \quad (1)$$

Where:

$V_{R1} = V_{PS} – V_{CC}$
$I_{R1} = I_{R2} + I_{CC}$
$I_{R2} = V_{CC}/R_2$
$I_{CC} = 100\ \mu A$
$R_2 = 10\ k\Omega$

The generalized formula for R_1 can be expanded, by substitution, to:

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

The following tables show the range of R_1 based on a 5-V supply voltage (V_{PS}), 3.3-V input signal (V_{IH}), 2-V and 2.4-V V_{OH} level with up to 30-mA $I_{(I)}$ through the switch. These tables allow the designer to choose the correct resistor for the design, based on design requirements.

V_{IN} = 3.3 V, $V_{OH(MIN)}$ = 2 V, I_{CC} = 100 µA				
I_I THROUGH THE SWITCH	**REQUIRED V_{CC} (V)**	**R_1 AT V_{PS} = 4.5 V (kΩ)**	**R_1 AT V_{PS} = 5 V (kΩ)**	**R_1 AT V_{PS} = 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_{IN} = 3.3 V, $V_{OH(MIN)}$ = 2.4 V, I_{CC} = 100 µA				
I_I THROUGH THE SWITCH	**REQUIRED V_{CC} (V)**	**R_1 AT V_{PS} = 4.5 V (kΩ)**	**R_1 AT V_{PS} = 5 V (kΩ)**	**R_1 AT V_{PS} = 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_{CC} 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.