Application Note

Schematic Checklist - A Guide to Designing with Auto-Bidirectional Translators

Michael Ikwuyum

ABSTRACT

This application note provides recommendations and a checklist to follow while creating or reviewing schematics for auto-bidirectional level shifters. Examples of such devices are the TXS, TXB and LSF device families. These devices are typically designed with limited drive strength, allowing their hosts to overdrive them for any direction. Such auto-bidirectional devices can be very sensitive to many factors when used in applications that are not auto-bidirectional. Intentional considerations should be ensured when designing with auto-bidirectional devices. Section 1.2 shows examples of auto-bidirectional use-cases.

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Trademarks

1 Introduction

TXB, TXS, and LSF device families are recommended for auto-bidirectional applications and TXU, TXV, LXC, LVC, AXC, AVC, AUP, LVxT families are recommended for applications where individual channels are used for a fixed directional signal.

1.1 Device Applicability

This application note applies to the following devices:

- TXS, TXB and LSF device families

1.2 When to Use or Not Use Auto-Bidirectional Devices

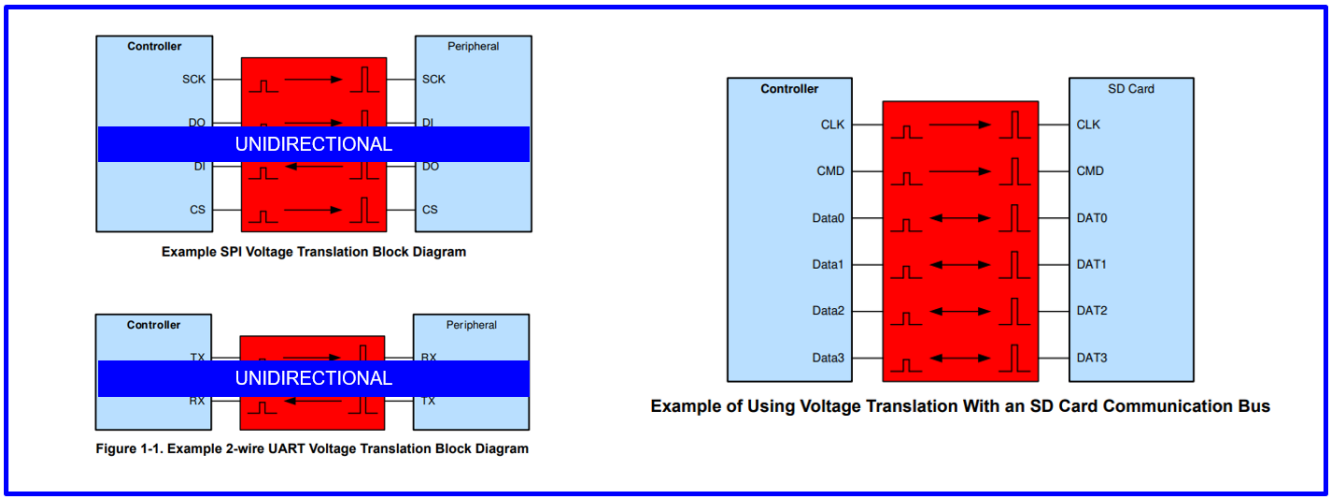

Figure 1-1. Differences Between Unidirectional and Auto-Bidirectional Signals

Each channel of unidirectional signals are directed towards a fixed direction while each channel of auto-bidirectional signals can be directed for both directions. Check for the direction of the application's signal or protocol and review this checklist with the latest data sheet documentation. Below are examples showing auto-bidirectional signals. See Section 2.7 for a full list of typical applications with their device recommendations.

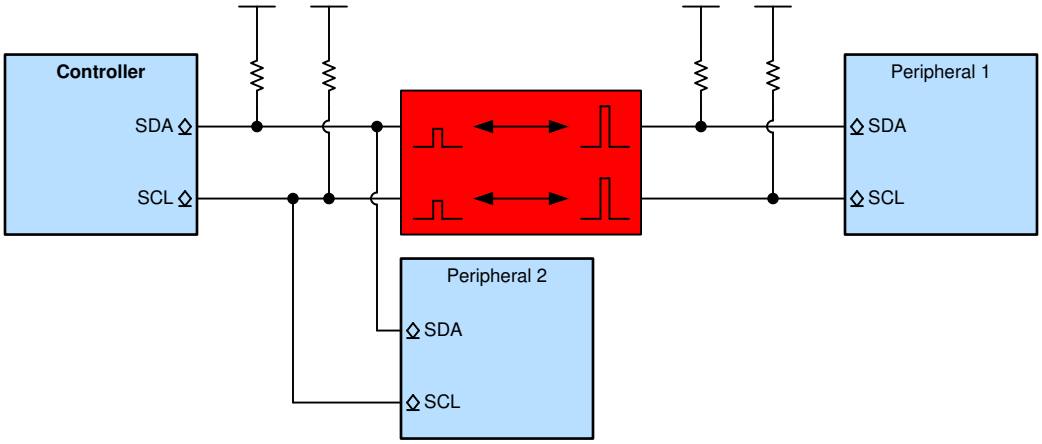

Figure 1-2. Example of Using Voltage Translation With an I2C Communication Bus

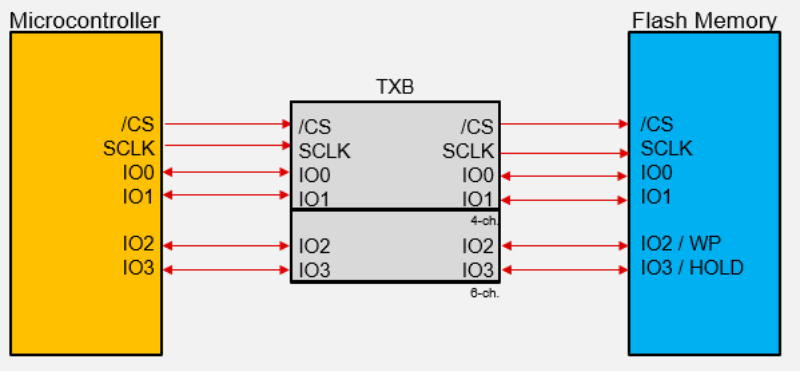

Figure 1-3. Example of Using Voltage Translation With Quad-SPI

2 Recommendations Specific to TXB, TXS, LSF

2.1 Before You Begin

2.1.1 Documentation

Make sure you have the latest version of all documentation and data sheets.

Note

There is a Notifications button on each ti.com device product folder. Registration here enables proactive automatic notification of device errata.

2.2 Power Supplies

2.2.1 Biasing Requirements

- **TXB or TXS**: Make sure supply voltages match data sheet recommendations for $V_{CCA} \leq V_{CCB}$.
- **LSF**: Make sure supply voltages match data sheet recommendations for $V_{ref\_B} \geq V_{ref\_A} + 0.8V$.
  - If level-shifting voltage levels conflicting with the above for LSF, pull-ups to voltage supplies different from V_{ref} can be populated on the inputs or outputs.
  - If LDOs are used, make sure LDO used can sink current flowing from V_{ref_B} into V_{ref_A}. With the recommended LSF 200kΩ bias resistor, current = (V_{ref_B} - V_{ref_A} - 0.8V) / 200kΩ.
    - Or, a 100kΩ weak pull-down resistor on V_{ref_A} to the output of the regulator is recommended.

2.2.2 Decoupling Capacitors

During transitions, level-shifters can draw large transient currents from the power supply. Decoupling capacitors prevents voltage droops on the power rails by bypassing the power supply and creating a low-impedance path for high-frequency signals. This makes sure the level-shifter is provided a clean and stable supply voltage.

A typical recommendation is 0.1µF, to help mitigate noise from power supplies. Place decoupling capacitors as close as possible to V_{CC} pins on the printed circuit board layout.

2.2.3 Power Sequencing

- TXB, TXS and LSF devices do not have any specific power sequence requirement.
- Make sure the OE pin is configured to keep the device disabled until both supplies are stable.

2.3 Output Enable Pins

- Never leave floating.
- Connect directly to V_{CC} or GND (or drive HIGH or LOW with a control signal).
  - Can use pull-ups or pull-downs when driven by a control signal. 10 kΩ is typical.
  - Pull-down is only required if LOW is needed on start-up, then driven HIGH with an MCU or other signals.
- **For LSF**: Make sure the EN pin is shorted to V_{ref_B} with 200 kΩ (internally done for LSF0204 and needs to be done externally for LSF010x).

2.4 Input or Output Pins

Make sure your input or output pins meet the data sheet recommendations. For example:

- Data rate frequency.
- Load capacitance.
- Recommended to keep trace lengths and loading as minimal as possible. Note, connectors add to the lumped capacitive loading.
- Double check proper voltage levels for inputs (follow the device-specific VIH / VIL specification in the data sheet). Devices are over-voltage tolerant and inputs can be ≥ V_{CC} within the data sheet's recommended operating conditions.
- Series resistors used should be sufficient with the device's output impedance and transmission line used. For more information, see [FAQ] Can I estimate appropriate dampening resistor value for level-shifter outputs?
- Not recommended to have delay (RC) circuitry tied to input pins to avoid violating the data sheet's input transition spec. Violations can result to shoot-through currents and oscillations. For more information,

see section 3 of *Do's and Don'ts for TXB and TXS Voltage Level-Shifters with Edge Rate Accelerators*, application note and Implications of Slow or Floating CMOS inputs.

2.5 Unused Pins

Unused pins for the TXB, TXS and LSF devices can be left disconnected (with the exception of the OE pin).

2.6 Pull-Ups and Pull-Downs

- TXB and TXS devices are sensitive to external pull-up or pull-down resistors due to the internal pull-up resistors present in the TXS device and the internal serial resistors present in the TXB device.
  - V_{OL} and V_{OH} levels are impacted with external pull-up and pull-down resistors.
  - Pull-up or pull-down resistor greater than 50 kΩ is recommended.
- LSF family is recommended for auto-bidirectional applications where external pull-up resistors are required. Pull-downs are not recommended as they create a voltage divider network with the pull-ups used.
  - **LSF Up translate with pull-ups:**
    - Required on the higher voltage side (B-side).
    - Required on the lower voltage side (A-Side) only if outputs are open-drain or with leakage > 1 µA.
  - **LSF Down translate with pull-ups:**
    - Not required if leakage into the receiver is < 1 µA.

2.7 Recommended Translator by Interface

Table 2-1. Recommended Translator by Interface

	Translation Level	
Interface	**Up to 3.6V**	**Up to 5.5V**
FET Replacement	2N7001T	SN74LXC1T45 / TXU0101
1 Bit GPIO / Clock Signal	SN74AXC1T45	SN74LXC1T45 / TXU0101
2 Bit GPIO	SN74AXC2T245	SN74LXC2T45 / TXU0102
2-Pin JTAG / UART	SN74AXC2T45	SN74LXC2T45 / TXU0202
I2C / MDIO / SMBus	TXS0102 / LSF0102	TXS0102 / LSF0102
IC-USB	SN74AVC2T872 / TXS0202	N/A
4 Bit GPIO	SN74AXC4T245	TXB0104 / TXU0104
UART	SN74AXC4T245	TXB0104 / TXU0204
SPI	SN74AXC4T774	TXU0304
Quad-SPI	TXB0106	TXB0106
JTAG	SN74AXC4T774 / TXB0104	TXB0104 / TXU0304
I2S / PCM	SN74AXC4T774 / TXB0104	TXB0104 / TXU0204
SDIO / SD / MMC	TXS0206 / TWL1200	N/A
6 Bit RGMII	TXV0106	N/A
8 Bit GPIO / RGMII	TXV0108	SN74LXC8T245

For more information on specific interfaces, see Voltage Translation Application Quick Reference

3 Summary

Step	Checklist	Comments
1	Verify the interface	See Section 2.7 Open-drain interfaces – TXS or LSF devices. Push-Pull interfaces – TXB or TXS or LSF devices.
2	Verify power supplies are biased correctly	TXB and TXS: $V_{CCA} \leq V_{CCB}$ is recommended LSF: $V_{ref\_A} + 0.8V \leq V_{ref\_B}$ is recommended
3	Verify decoupling capacitors are used with all power supplies	0.1µF is recommended. Recommended to place cap as close as possible to the V_{CC} supply pin.
4	Verify the schematic pinout matches the data sheet pinout.	Unused I/Os can be left floating. Traces with used I/Os can be kept as short as possible.
5	Verify output capacitive load is minimal	Typically, up to 70pF unless specified in data sheets.
6	Verify that external pull-up or pull-down resistors are consistent with data sheet.	Pull-ups or pull-downs are not recommended for TXB and TXS. LSF can use pull-ups. Pull-downs not recommended.

4 References

- Texas Instruments, *A Guide to Voltage Translation with TXB-Type Translators*, application note.
- Texas Instruments, *A Guide to Voltage Translation with TXS-Type Translators*, application note.
- Texas Instruments, *Do's and Don'ts for TXB and TXS Voltage Level-Shifters with Edge Rate Accelerators*, application note.
- Texas Instruments, *Effects of External Pullup and Pulldown Resistors on TXS and TXB Devices*, application note.
- Texas Instruments, *Voltage-Level Translation with the LSF Family*, application note.
- Texas Instruments, *Factors Affecting VOL for TXS and LSF Auto-Bidirectional Translators*, application note.
- Texas Instruments, *Implications of Slow or Floating CMOS inputs*, application note.

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