Application Report
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Factors Affecting V_{OL} for TXS and LSF Auto-bidirectional Translation Devices

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ABSTRACT

The TXS and LSF families of translators differ from other translator families, because their outputs are not driven by buffers. Instead, the TXS and LSF families use internal or external pullup resistors to drive logic high, and an internal pass transistor that lets the host device to drive logic low. This results in a V_{OL} (Logic low output voltage) level that is a function of V_{IL}(Logic low Input voltage), the resistance of the internal pass transistor, and the current through the pass transistor. In Section 1 and Section 2, the relationship between V_{OL}, V_{IL}, pass transistor resistance and the pass transistor current are examined in detail for the TXS and LSF families of passive auto-bidirectional translators.

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1 V_{OL} Versus V_{IL} of TXS Type Translators

The internal architecture of the TXS family of translators contains a pass transistor, internal pullup resistors on both the I/O ports, and One-shot edge accelerator circuitry. Figure 1 shows a simplified diagram of this internal architecture. For more information, see the A Guide to Voltage Translation With TXS-Type Translators application report.

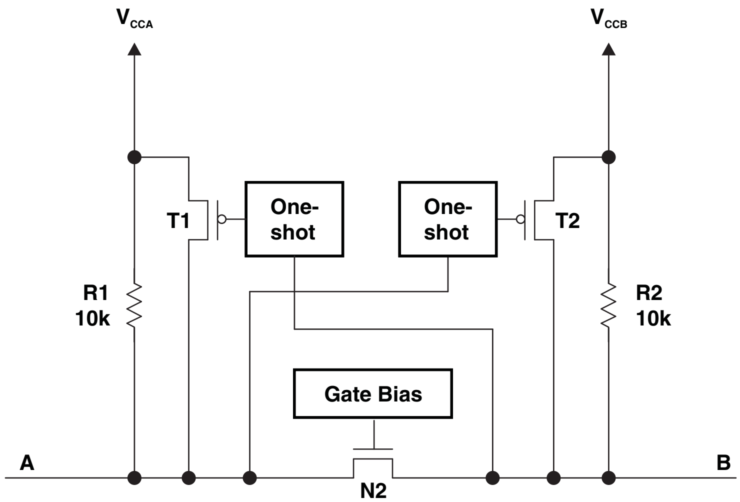

Figure 1. Simplified TXS Architecture

The pass transistor bias voltage, V_{BIAS}, is referenced to V_{CCI}, the input side supply voltage. When the voltage on one of the I/O lines drops below the threshold of the gate bias voltage, V_{BIAS}, the pass transistor turns on and the input tracks the output. In general, when the pass transistor stops conducting the voltage is roughly equal to Equation 1.

$$\frac{V_{CCI}}{2} \quad (1)$$

When the pass transistor is on, the output voltage is equal to the input voltage plus the voltage drop across the pass transistor. Therefore, as the current increases, the output voltage also increases, even with a constant input voltage. Likewise, if the input voltage increases, the output voltage also increases, even with a constant current. This implies that the V_{OL} voltage level is a function of the V_{IL} voltage level and the current flowing through the pass transistor.

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Figure 2 and Figure 3 show this relationship, where V_{OL} is plotted against V_{IL} at various current levels for the TXS0108E and TXS0101 voltage translators.

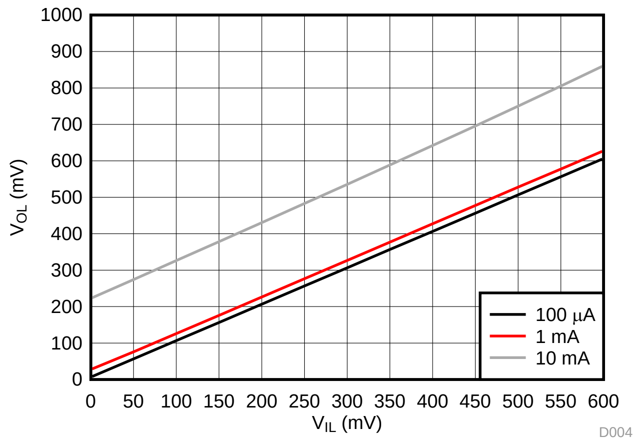

Figure 2. TXS0101 V_{OL} Versus V_{IL}

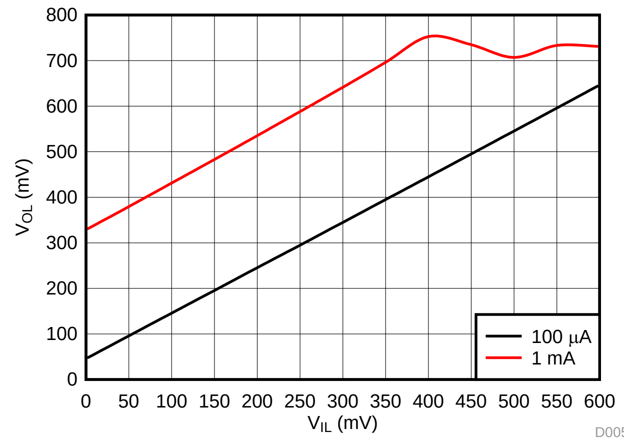

Figure 3. TXS0108E V_{OL} Versus V_{IL}

As shown in Figure 2 and Figure 3, there is a linear relationship between V_{OL} and V_{IL} as long as the current remains constant and the voltage at the output does not exceed the threshold voltage of the pass transistor. The TXS0101 can maintain a reasonable V_{OL}, with up to 10 mA of current through the pass transistor with the input at 0 V. However, the TXS0108E device cannot maintain a reasonable V_{OL} for current levels above 1 mA. With 1 mA through the pass transistor, the TXS01018E device also begins to oscillate at the output as the input voltage reaches 400 mV, because the output voltage begins to exceed the threshold voltage of the pass transistor. At 100 µA, the TXS0101 and TXS0108E devices can both maintain a V_{OL} under 50 mV with V_{IL} at 0 V.

1.1 *Summary for V_{OL} Versus V_{IL} of TXS Type Translators*

When driving the line low, the voltage at the output is equal to Equation 2.

$$V_{OL} = V_{IL} + I_{OL} \times R_{pass} \quad (2)$$

where

- R_{pass} is the on-state resistance of the pass transistor.
- I_{OL} is the current flowing through the pass transistor.

Therefore, to maintain the lowest possible V_{OL} two practices must be observed. First, the V_{IL} must be kept as close as possible to 0 V, and second, the current through the pass transistor must be kept as low as possible. To prevent excessive current through the pass transistor, strong external pullup resistors of less than 50 kΩ must be avoided. The effects of external resistors are described in the *Effects of External Pullup and Pulldown Resistors on TXS and TXB Devices* application report.

2 V_{OL} Versus V_{IL} of LSF Type Translators

Like the TXS family, the LSF family also contains a pass transistor that conducts when driving the line low. The LSF family differs in that there are no internal pullup resistors; however, the behavior of the pass transistor is identical with the exception of the pass transistor gate reference, which is supplied by the EN pin, as shown in Figure 4. See the *Voltage Translation With the LSF Family* application report, watch the LSF Logic Minute videos to understand more about the LSF device operation and its applications.

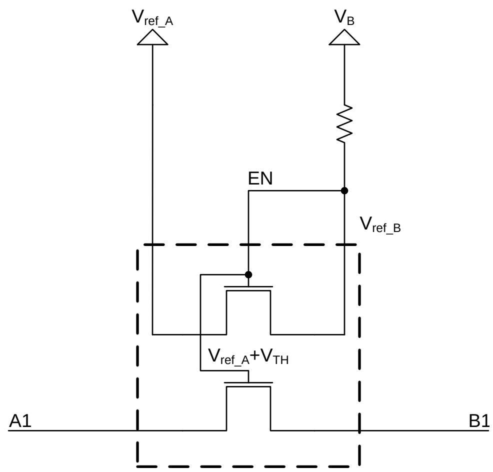

Figure 4. LSF010x Simplified Architecture

When the pass transistor is on, the output voltage is equal to the input voltage plus the voltage drop across the pass transistor. Therefore, as the current increases, the output voltage also increases, even with a constant input voltage. Likewise, if the input voltage increases, the output voltage also increases, even with a constant current. This implies that the V_{OL} voltage level is a function of the V_{IL} voltage level and the current flowing through the pass transistor. Figure 5 shows this relationship, where V_{OL} is plotted against V_{IL} at various current levels for the LSF0108 device.

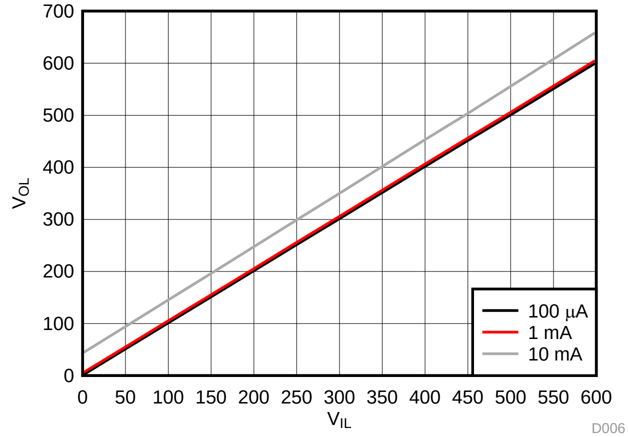

Figure 5. LSF0108 V_{OL} Versus V_{IL}

As shown in Figure 5, there is a linear relationship between V_{OL} and V_{IL}, given a constant current. The LSF translators can maintain a V_{OL} less than 100 mV, even at 10 mA, indicating a lower on-state resistance of the pass transistor when compared to the TXS family of translators.

2.1 Summary for V_{OL} Versus V_{IL} of LSF-Type Translators

When driving the line low, the voltage at the output is equal to Equation 3.

$$V_{OL} = V_{IL} + I_{OL} \times R_{pass} \quad (3)$$

where

- R_{pass} is the on-state resistance of the pass transistor.
- I_{OL} is the current flowing through the pass transistor.

Therefore, to maintain the lowest possible V_{OL} two practices must be observed. First, V_{IL} must be kept as close as possible to 0 V. Second, the current through the pass transistor must be kept as low as possible.

3 References

- Texas Instruments, Basics of Voltage-Level Translation, application report
- Texas Instruments, Voltage Translation With the LSF Family, application report
- Texas Instruments, A Guide to Voltage Translation With TXB-Type Translators, application report
- Texas Instruments, A Guide to Voltage Translation With TXS-Type Translators, application report
- Texas Instruments, Effects of External Pullup and Pulldown Resistors on TXS and TXB Devices, application report

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