Application Report
SCEA054A–September 2017–Revised March 2018

Effects of External Pullup and Pulldown Resistors on TXS and TXB Devices

Shreyas Rao, Adrian Ozer

ABSTRACT

The TXS and TXB family of devices belong to the auto-bidirectional translation products from TI. These devices can be sensitive to external pullup or pulldown resistors due to the internal pullup resistors present in the TXS device and the internal serial resistors present in the TXB device. In this application note, the effects of external pullup and pulldown resistors on V_{OL} and V_{OH} levels of the TXS and TXB family of devices are examined. As external pullup or pulldown resistors impact the way the output behaves in a design, a high value of pullup or pulldown resistors greater than 50 kΩ is beneficial to prevent performance degradation.

Contents

List of Figures

List of Tables

Trademarks

All trademarks are the property of their respective owners.

1 External Resistors on TXS and TXB Translators

1.1 Terminology

V_{OL} – The voltage level at the output when driving logic low. For more detailed information, see the application note on *Understanding and interpreting Standard -logic data sheets*

V_{OH} – The voltage level at the output when driving logic high. For more detailed information, see the application note on *Understanding and interpreting Standard -logic data sheets*

TXS - TI auto bidirectional translation switch type device family. For more detailed information, see the application note on *A Guide to Voltage Translation With TXS-Type Translators*

TXB - TI auto bidirectional translation buffered type device family. For more detailed information, see the application note on *A Guide to Voltage Translation With TXB-Type Translators*

R_{PD} - Pulldown resistor

R_{PU}- Pullup resistor

1.2 TXS Pullup Resistor Analysis

The TXS family of translators incorporates internal pullup resistors designed to hold the output when driving logic high. The internal pullup resistor is fixed at 10 kΩ for the TXS0101, TXS0102, and TXS0104E translators, whereas the TXS0108E translator has dynamic pullup resistors that change value depending on whether the output is driving a high or low. When driving a high, the pullup resistor value is 4 kΩ and when driving a low, the pullup resistor value is 40 kΩ. See Figure 1 for a simplified diagram of the output configuration.

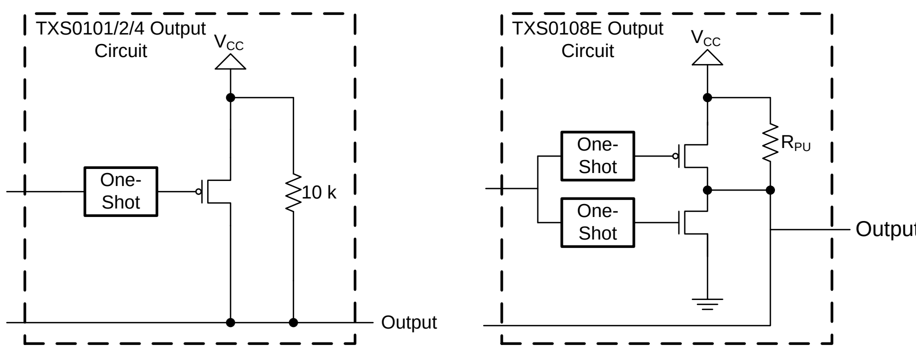

Figure 1. TXS010x Simplified Output Circuit

The one-shot circuit is designed to momentarily increase the drive strength on a transitioning edge. When in a DC steady state, the output is held high by the internal pullup resistor. Due to this, adding external pullup or pulldown resistors can impact the way the output behaves. To demonstrate the resulting changes, the output of the TXS0108E is measured across four different pullup and pulldown resistor values ranging from 4.7 kΩ to 100 kΩ. See Figure 2 for the test setup.

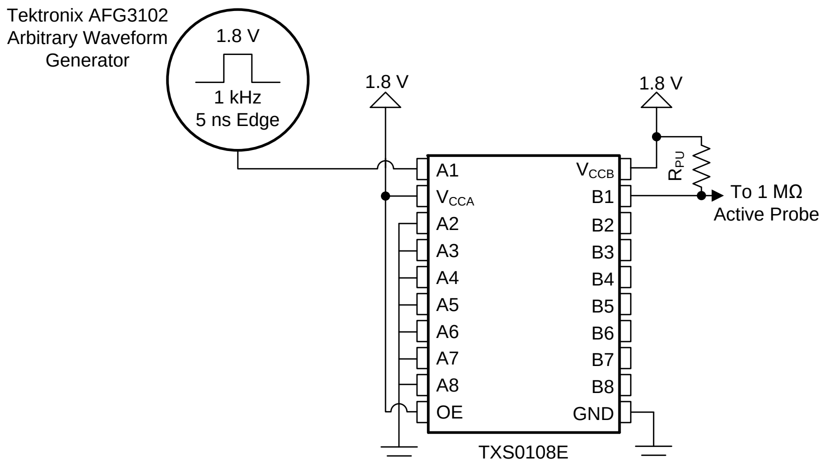

Figure 2. TXS0108E Pullup Test Setup

Input A1 uses a 1-kHz signal at 1.8 V with 5-ns rising and falling edges. The output, B1, is pulled up to 3.3 V through a pullup resistor and measured using a 1-MΩ active probe. All other input channels are grounded.

Figure 3 shows the results. Channel 1 (purple) represents the input signal and Channel 3 (green) represents the output signal. The corresponding pullup resistor value is shown in the upper left corner of each oscilloscope screenshot.

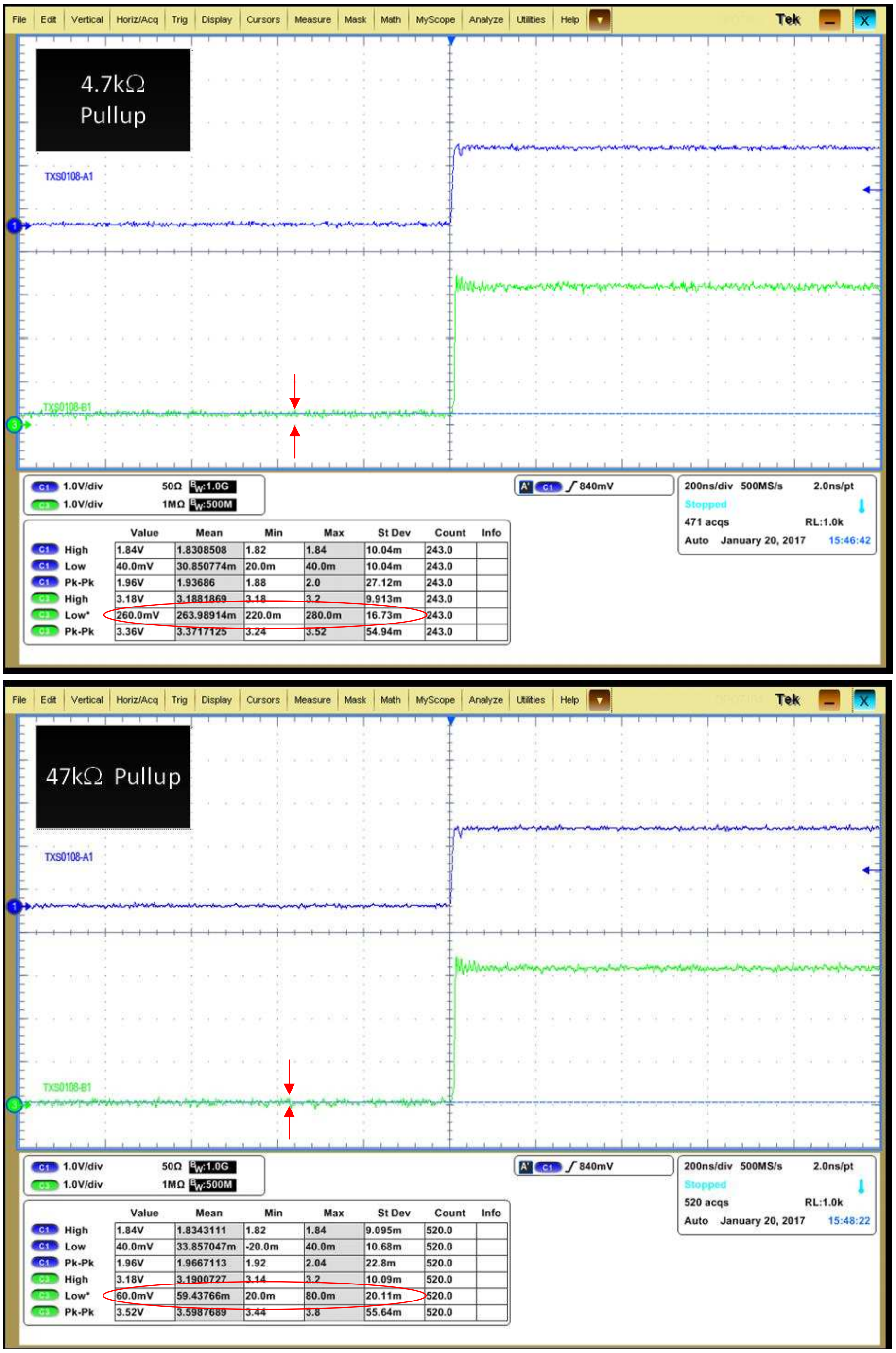

Figure 3. TXS0108E Pullup Resistor Output

The results in Figure 3 illustrate the changes that pullup resistors have on the V_{OL} levels of TXS type translators. The baseline V_{OL} with no pullup resistor is 30 mV compared to the V_{OL} of 264 mV using a 4.7-kΩ pullup resistor due to the parallel combination of the external pullup resistor with the internal 40 kΩ while driving low. This is attributed to the additional current through the pass transistor, resulting in a larger voltage drop across the pass transistor.

R_{EQ}= (40 × 4.7) / (40 + 4.7) = 4.2 kΩ; where R_{EQ} is the equivalent resistor due to the parallel combination of the external pullup resistor with the internal 40 kΩ while driving low.

Adding a strong external pullup resistor increases the current seen at that I/O port because of the reduced parallel resistance of the internal pullup and the external pullup. The result is that the increase in V_{OL} is dependent on both the current sinking capability of the external driving device and the resistance of the internal pass transistor. See Table 1 for a summary of the pullup results.

Table 1. TXS0108E Pullup Results Summary

RESISTOR VALUE (kΩ)	V_{OL} (V)	V_{OH} (V)
No external resistor	0.029	3.18
4.7	*0.264*	3.19
9.8	*0.169*	3.19
47	0.059	3.19
100	0.038	3.19

1.2.1 TXS Pulldown Resistor Analysis

The output of the TXS0108E is also measured across four different pulldown resistor values ranging from 4.7 kΩ to 100 kΩ. See Figure 4 for the test setup.

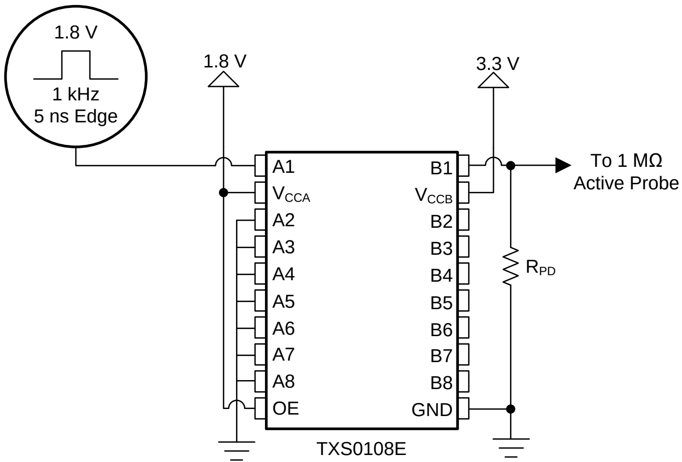

Figure 4. TXS0108E Pulldown Test Setup

Input A1 uses a 1-kHz signal at 1.8 V with 5-ns rising and falling edges. The output, B1, is pulled down to ground through a pulldown resistor and measured using a 1-MΩ active probe. All other input channels were grounded.

Figure 5 shows the results. Channel 1 (purple) represents the input signal and Channel 3 (green) represents the output signal. The pulldown resistor value used is shown in the upper left corner of each oscilloscope screenshot.

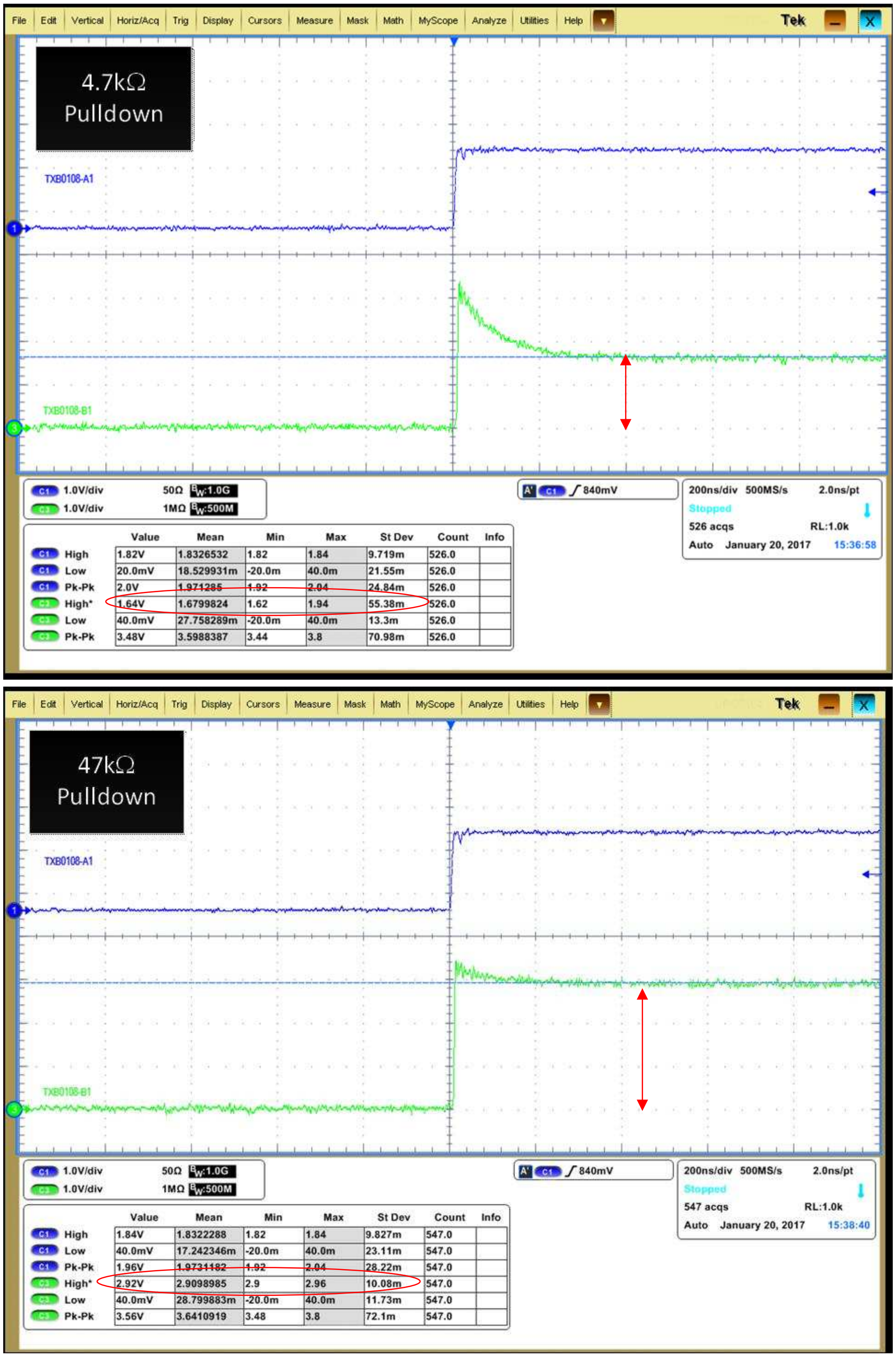

Figure 5. TXS0108E Pulldown Resistor Output

The results in Figure 5 illustrate the changes that pulldown resistors have on the V_{OH} levels of TXS type translators. The baseline V_{OH} with no pullup resistor is 3.18 V compared to the V_{OH} of 1.68 V using a 4.7-kΩ pulldown resistor.

The internal pullup resistor and the external pulldown resistor creates a voltage divider network, which causes a decrease in V_{OH}. The negative impact of pulldown resistors on V_{OH} demonstrates why the TXS family of translators must only be used to drive high-impedance loads. See Table 2 for a summary of the results.

Table 2. TXS0108E Pulldown Results Summary

RESISTOR VALUE (kΩ)	V_{OL} (V)	V_{OH} (V)
No external resistor	0.029	3.18
4.7	0.028	*1.68*
9.8	0.027	*2.18*
47	0.029	2.91
100	0.027	3.04

1.2.2 Conclusion

TXS type translators can be used with external pullup resistors without a significant impact on output voltage levels, provided that the driving device is capable of sinking the additional required current to pull the line low and the voltage drop across the internal pass transistor is not significant. Use Equation 1 to estimate the required current sinking capabilities of the driver:

$$I = \frac{V_{CCA}}{R_A} + \frac{V_{CCB}}{R_B} \quad (1)$$

R_A and R_B are equal to the equivalent parallel resistance of the external pullup resistor and the internal pullup resistor. For the TXS0101, TXS0102, and TXS0104E devices, the internal pullup resistance is equal to 10 kΩ when driving low. For the TXS0108E, the internal pullup resistance is equal to 40 kΩ when driving low. TI recommends that this current be limited to values under 1 mA for the TXS0108E and 10 mA for the TXS0101, TXS0102, and TXS0104E .

pulldown resistors must be avoided because of decreased V_{OH} levels. If pulldown resistors are necessary they must be limited to values of 50 kΩ or greater. The negative impact of pulldown resistors on V_{OH} levels also demonstrates why the TXS family of translators must only be used to drive high-impedance loads.

1.3 TXB Pullup and Pulldown Resistor Analysis

The TXB family of translators is designed to drive high-impedance loads, with the output driven by a 4-kΩ buffer when in a DC steady state. In this section, the impact of external resistors on V_{OH} and V_{OL} levels of TXB translators is examined. Figure 6 shows a simplified diagram of the TXB010x output.

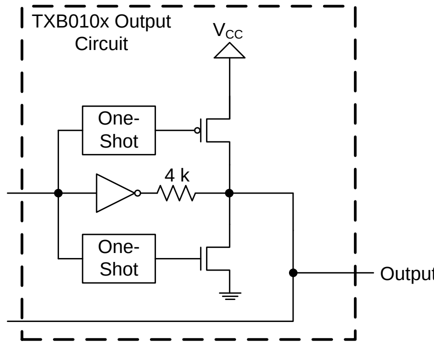

Figure 6. TXB010x Simplified Output Circuit

If strong external pullup or pulldown resistors are added, a resistor divider network is formed with the 4-kΩ buffer resulting in adverse changes in V_{OH} and V_{OL} levels. The output of the TXB0108 is measured across four different pullup and pulldown resistor configurations ranging from 4.7 kΩ to 100 kΩ. Figure 7 shows the test setup for the pullup resistor analysis.

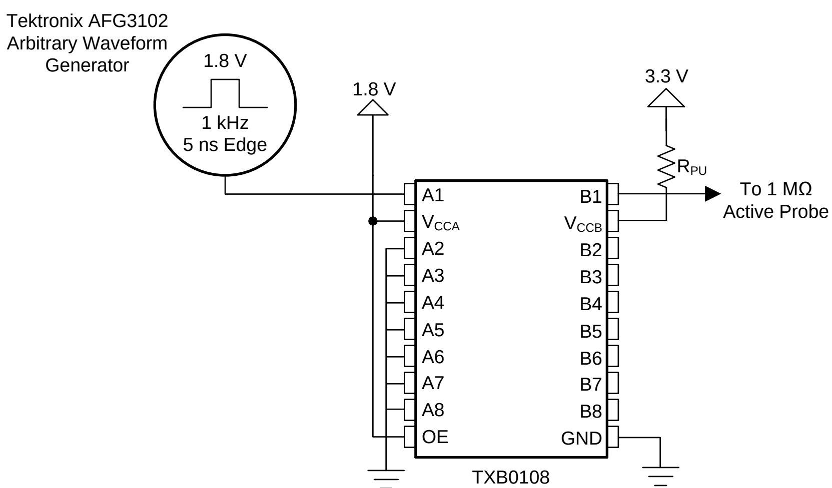

Figure 7. TXB0108 Pullup Test Setup

Input A1 uses a1-kHz signal at 1.8 V with 5-ns rising and falling edges. The output, B1, is pulled up to 3.3 V through a pullup resistor and measured using a 1-MΩ active probe. All other input channels are grounded.

Figure 8 shows the results. Channel 1 (green) represents the input signal and Channel 3 (purple) represents the output signal. The corresponding pullup resistor value is shown in the upper left corner of each oscilloscope screenshot.

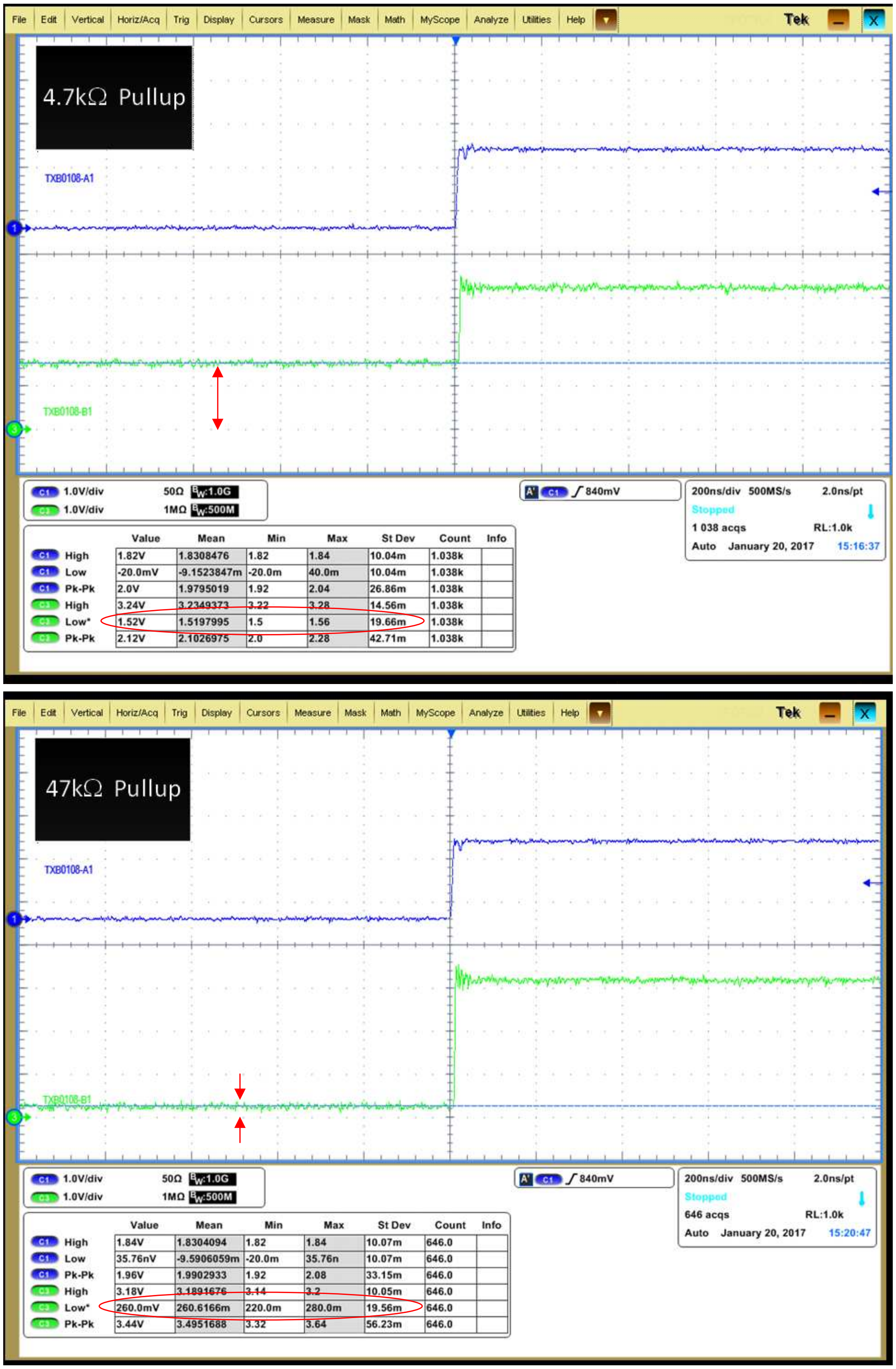

Figure 8. TXB0108 Pullup Resistor Output

The results in Figure 8 illustrate the impact that pullup resistors have on the V_{OL} levels of TXB type translators. The baseline V_{OL} with no pullup resistor is –6.8 mV compared to the V_{OL} of 1.52 V using a 4.7-kΩ pullup resistor. See Table 3 for a summary of the results.

Table 3. TXB0108 Pullup Results Summary

RESISTOR VALUE (kΩ)	V_{OL} (V)	V_{OH} (V)
No External Resistor	–0.007	3.19
4.7	*1.52*	3.23
9.8	*0.977*	3.21
47	0.26	3.19
100	0.11	3.19

1.3.1 TXB Pulldown Resistor Analysis

The output of the TXB0108 is also measured across four different pulldown resistor values ranging from 4.7 kΩ to 100 kΩ. Figure 9 shows the test setup.

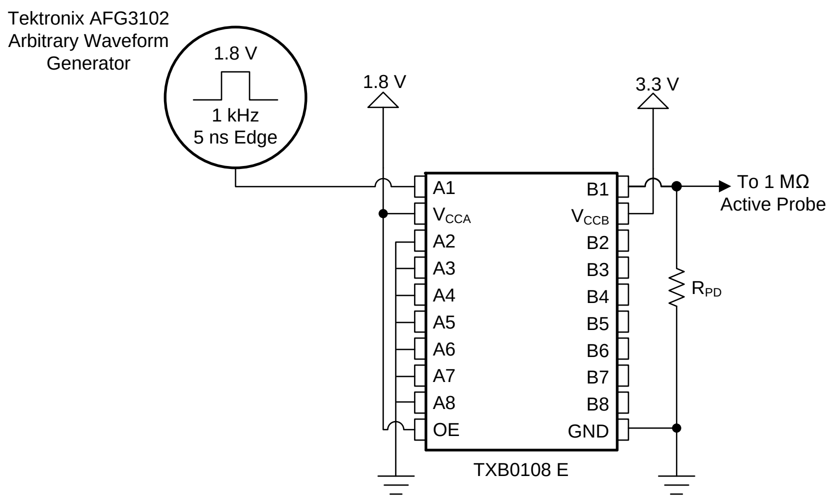

Figure 9. TXB0108 Pulldown Test Setup

Input A1 uses a 1-kHz signal at 1.8 V with 5-ns rising and falling edges. The output, B1, is pulled down to ground through a pulldown resistor and measured using a 1 MΩ active probe. All other input channels are grounded.

Figure 10 shows the results. Channel 1 (green) represents the input signal and Channel 3 (purple) represents the output signal. The pulldown resistor value used is shown in the upper left corner of each oscilloscope screenshot.

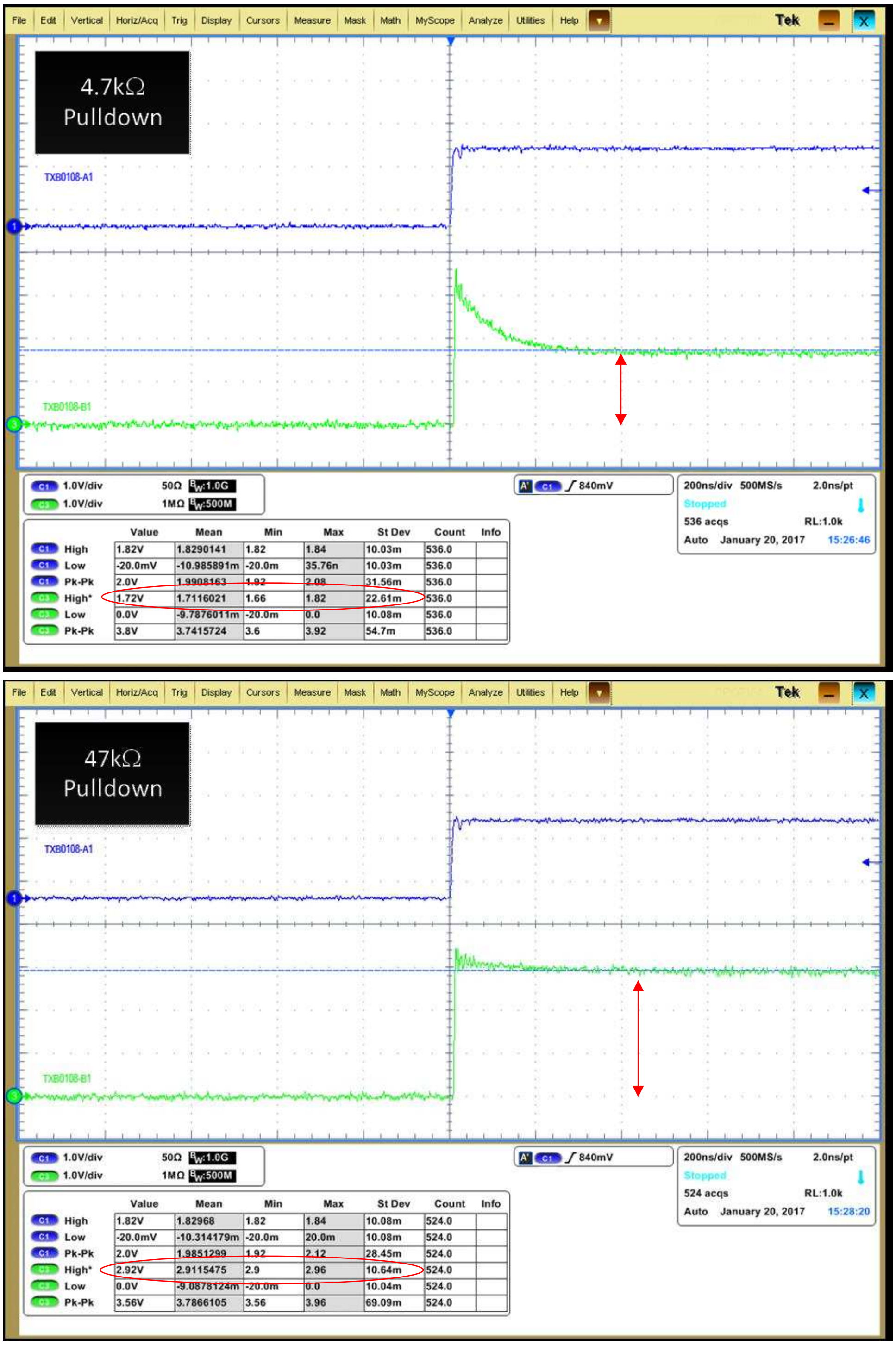

Figure 10. TXB0108 Pulldown Resistor Output

The results in Figure 10 illustrate the changes that pulldown resistors have on the V_{OH} levels of TXB type translators. The baseline V_{OH} with no pullup resistor is 3.98 V compared to the V_{OH} of 1.71 V using a 4.7-kΩ pulldown resistor. The negative impact of pulldown resistors on V_{OH} levels demonstrates why the TXB family of translators must only be used to drive high-impedance loads. See Table 4 for a summary of the results.

Table 4. TXB0108 Pulldown Results Summary

RESISTOR VALUE (kΩ)	V_{OL} (V)	V_{OH} (V)
No External Resistor	–0.007	3.19
4.7	–0.01	*1.71*
9.8	–0.01	*2.22*
47	–0.01	2.91
100	–0.012	3.04

1.3.2 Conclusion

Pullup and pulldown resistors of less than 50 kΩ must not be used with TXB translators because the internal 4-kΩ buffer and external resistors create a resistor divider network. Equation 2 provides an estimated calculation for the resulting V_{OL} based on the pullup value.

$$V_{OL} = \frac{4\ k\Omega}{4\ k\Omega + Rpu} \times V_{CCO} \tag{2}$$

In Equation 2, substitute in the external pullup resistor value for R_{pu} and the V_{CC} voltage at the output port for V_{CCO} to obtain the estimated V_{OL} value.

Similarly, the resulting V_{OH} value based on an external pulldown resistor can be estimated using Equation 3.

$$V_{OH} = \frac{Rpd}{Rpd + 4\ k\Omega} \times V_{CCO}$$

where

- R_{pd} is the pulldown resistor value
- V_{CCO} is the voltage supply of the output port (3)

From these results, only weak pullup or pulldown resistors (> 50 kΩ) must be used with TXB devices. If stronger external pullup resistors are required, refer to the TXS family or LSF family of devices.

2 References and Further Reading

2.1 Relevant Technical Documents

- *Basics of Voltage-Level Translation*
- *Selecting the Right Level-Translation Solution*
- *Voltage-Level Translation With the LSF Family*
- *A Guide to Voltage Translation With TXS-Type Translators*
- *A Guide to Voltage Translation With TXB-Type Translators*
- *Voltage Translation Between Different Logic Voltage Standards*