

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

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## 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 k $\Omega$  is beneficial to prevent performance degradation.

## Contents

1	External Resistors on TXS and TXB Translators .....	2
2	References and Further Reading .....	13

## List of Figures

1	TXS010x Simplified Output Circuit .....	2
2	TXS0108E Pullup Test Setup .....	3
3	TXS0108E Pullup Resistor Output .....	4
4	TXS0108E Pulldown Test Setup .....	6
5	TXS0108E Pulldown Resistor Output .....	7
6	TXB010x Simplified Output Circuit .....	9
7	TXB0108 Pullup Test Setup .....	9
8	TXB0108 Pullup Resistor Output .....	10
9	TXB0108 Pulldown Test Setup .....	11
10	TXB0108 Pulldown Resistor Output .....	12

## List of Tables

1	TXS0108E Pullup Results Summary .....	5
2	TXS0108E Pulldown Results Summary .....	8
3	TXB0108 Pullup Results Summary .....	11
4	TXB0108 Pulldown Results Summary .....	13

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# 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](#)

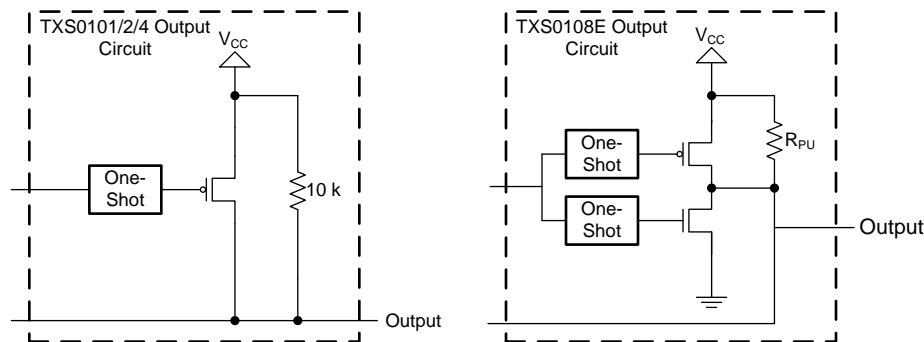
TXB - TI auto bidirectional translation buffered type device family. For more detailed information, see the application note on [A Guide to Voltage Translation With TXB-Type Translators](#)

$R_{PD}$  - Pulldown resistor

$R_{PU}$  - Pullup resistor

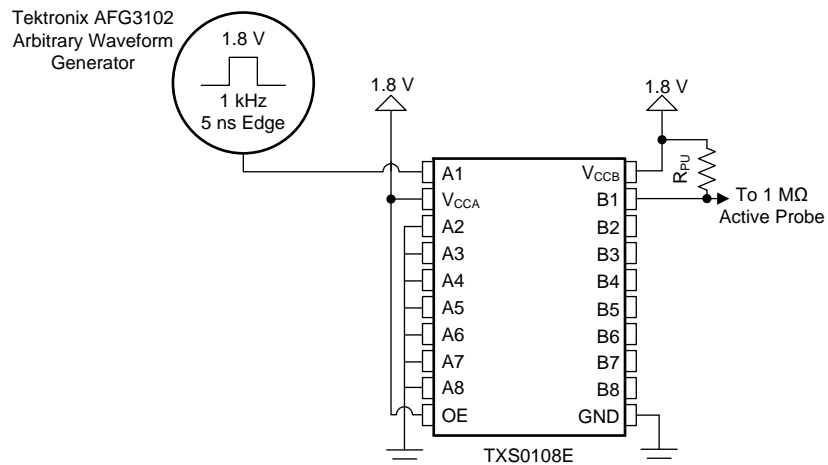
## 1.2 TXS Pullup Resistor Analysis

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.

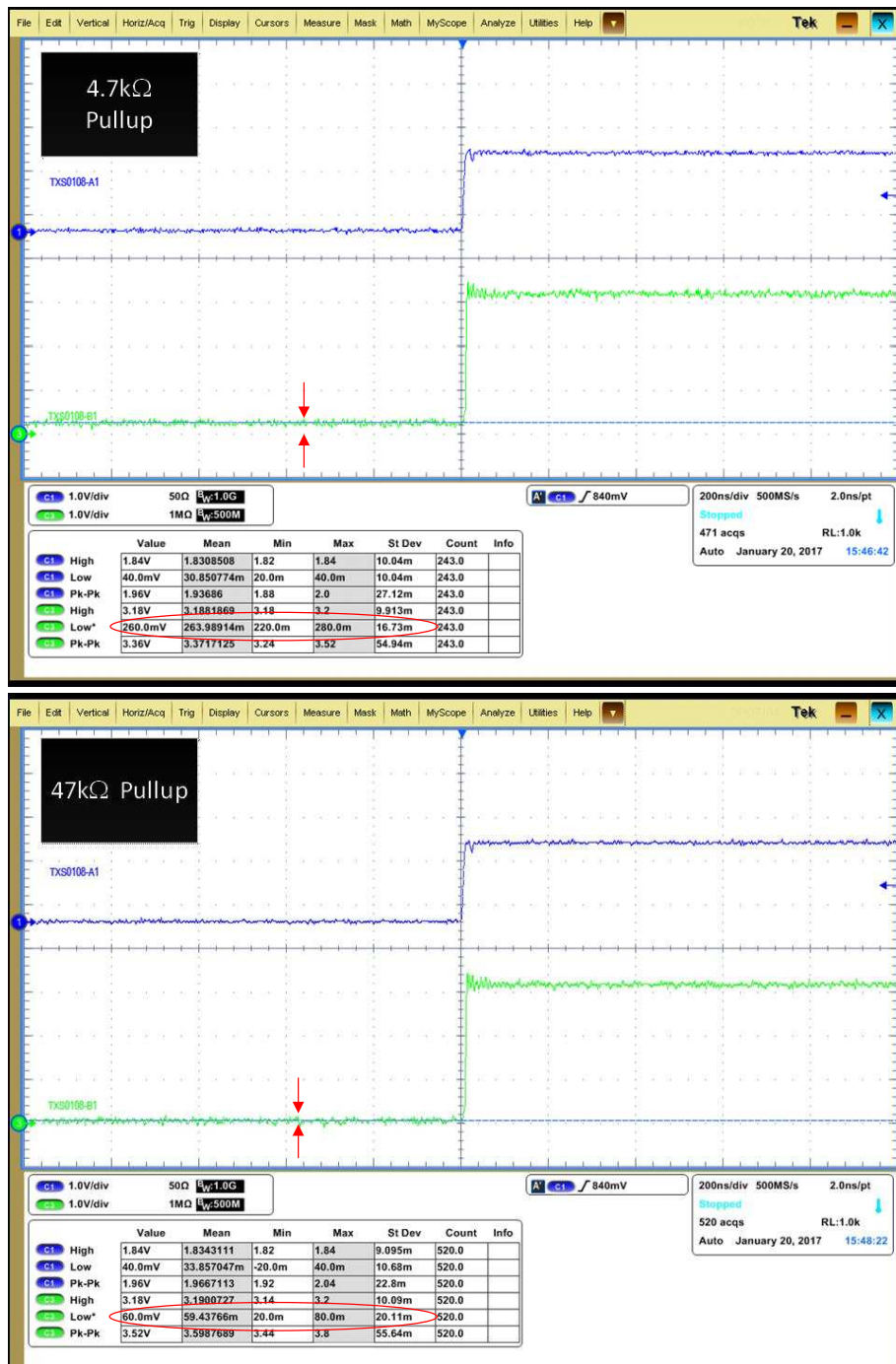


Figure 3. TXS0108E Pullup Resistor Output

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.

$R_{EQ} = (40 \times 4.7) / (40 + 4.7) = 4.2 \text{ k}\Omega$ ; 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.

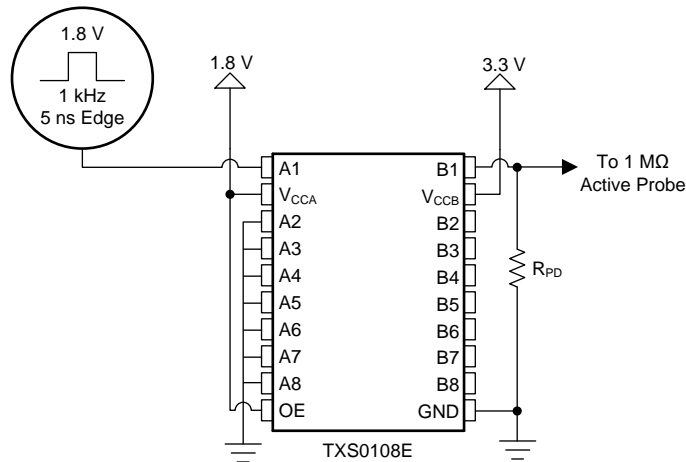
Adding a strong external pullup resistor increases the current seen at that I/O port because of the reduced parallel resistance of the internal pullup and the external pullup. The result is that the increase in  $V_{OL}$  is dependent on both the current sinking capability of the external driving device 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 (k $\Omega$ )	$V_{OL}$ (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 k $\Omega$  to 100 k $\Omega$ . 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-M $\Omega$  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.

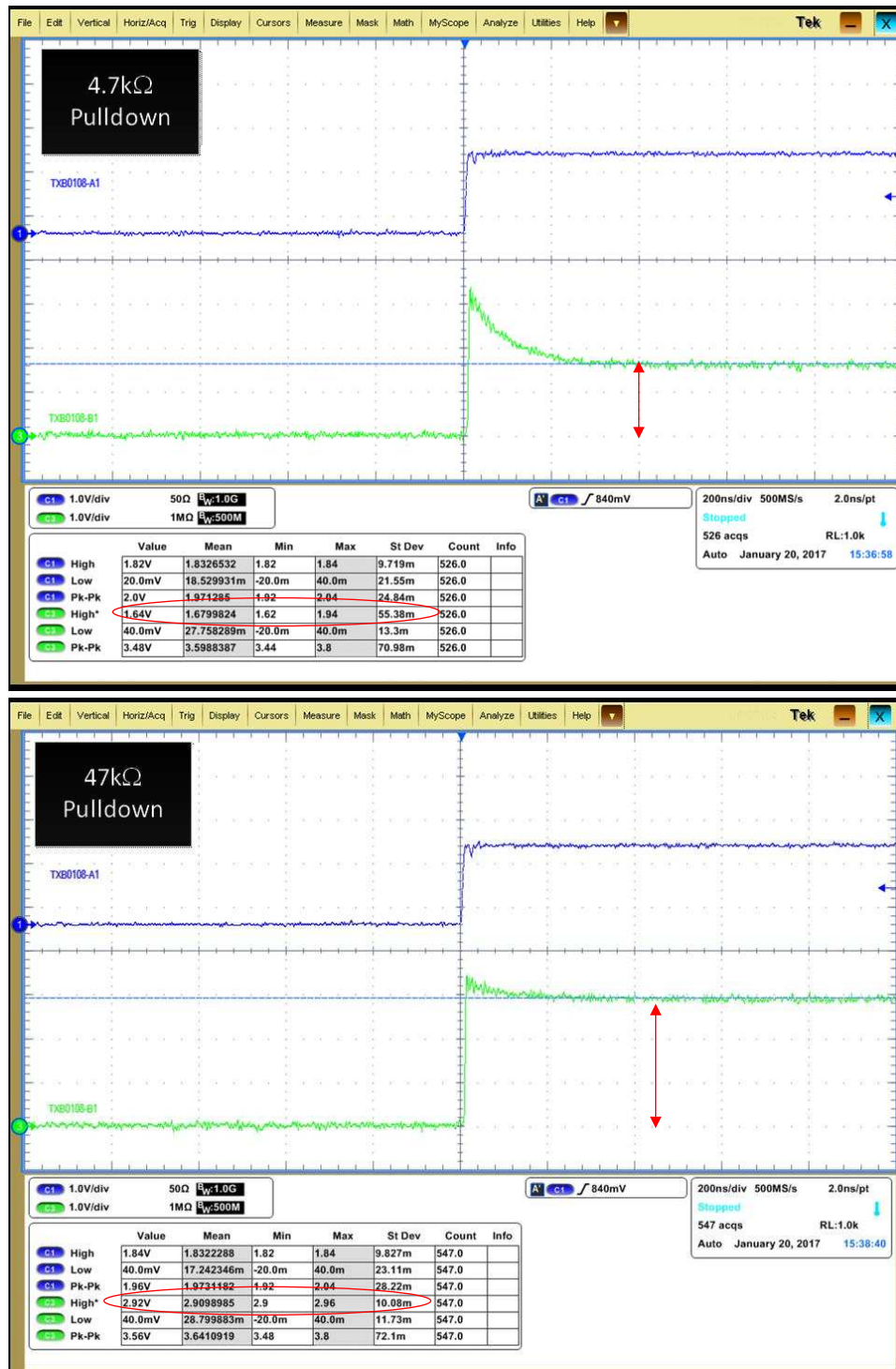


Figure 5. TXS0108E Pull-down Resistor Output

The results in Figure 5 illustrate the changes that pull-down 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 pull-down 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 (k $\Omega$ )	$V_{OL}$ (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 k $\Omega$  when driving low. For the [TXS0108E](#), the internal pullup resistance is equal to 40 k $\Omega$  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 k $\Omega$  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-k $\Omega$  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.

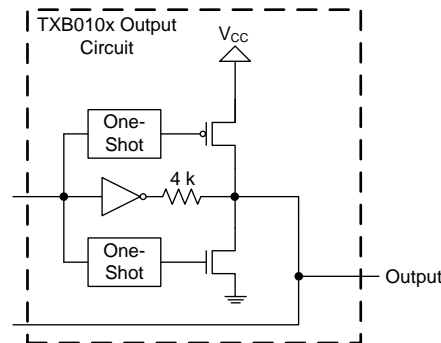


Figure 6. TXB010x Simplified Output Circuit

If strong external pullup or pulldown resistors are added, a resistor divider network is formed with the 4-k $\Omega$  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 k $\Omega$  to 100 k $\Omega$ . Figure 7 shows the test setup for the pullup resistor analysis.

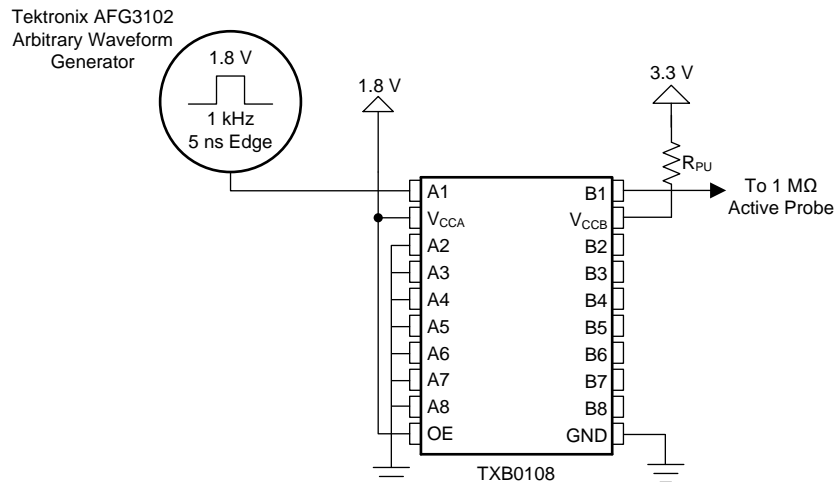


Figure 7. TXB0108 Pullup Test Setup

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-M $\Omega$  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.

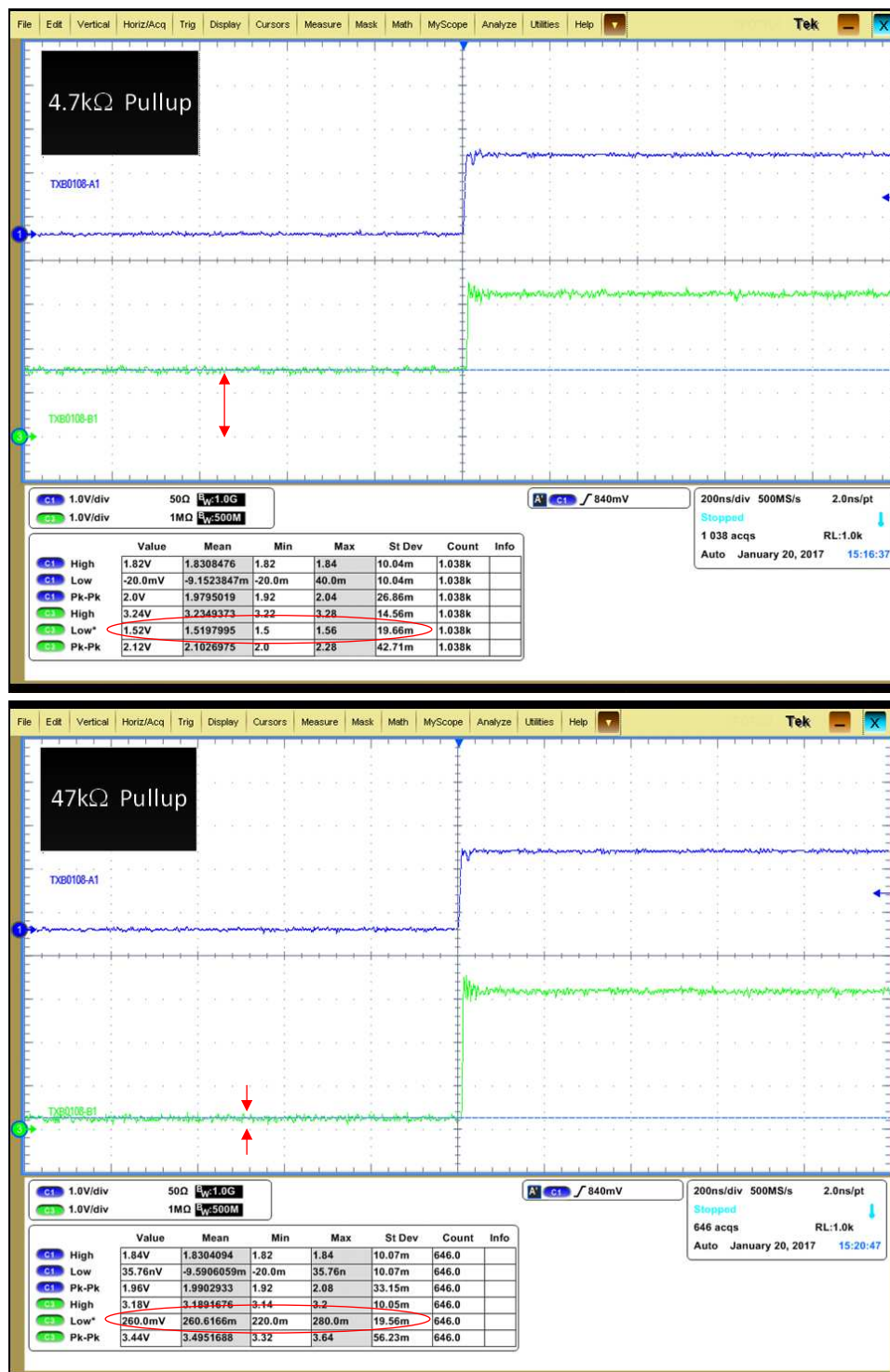


Figure 8. TXB0108 Pullup Resistor Output

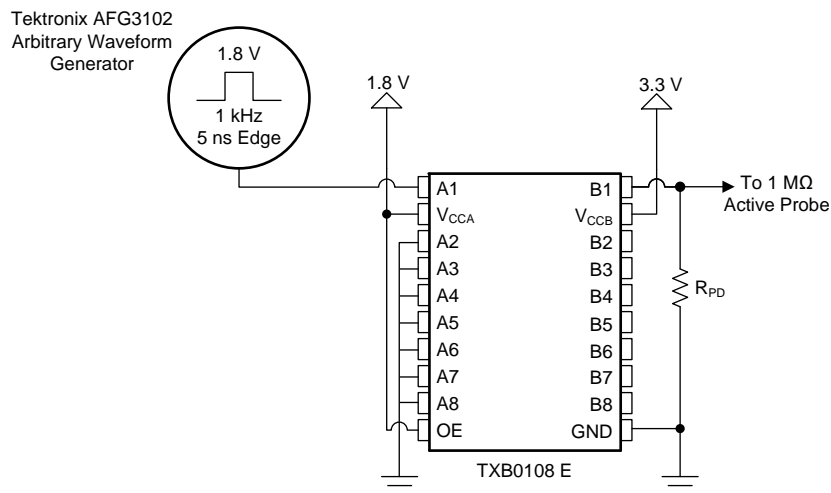
The results in Figure 8 illustrate the impact that pullup resistors have on the  $V_{OL}$  levels of TXB type translators. The baseline  $V_{OL}$  with no pullup resistor is  $-6.8$  mV compared to the  $V_{OL}$  of  $1.52$  V using a  $4.7$ -kΩ pullup resistor. See Table 3 for a summary of the results.

**Table 3. TXB0108 Pullup Results Summary**

RESISTOR VALUE (kΩ)	V <sub>OL</sub> (V)	V <sub>OH</sub> (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.

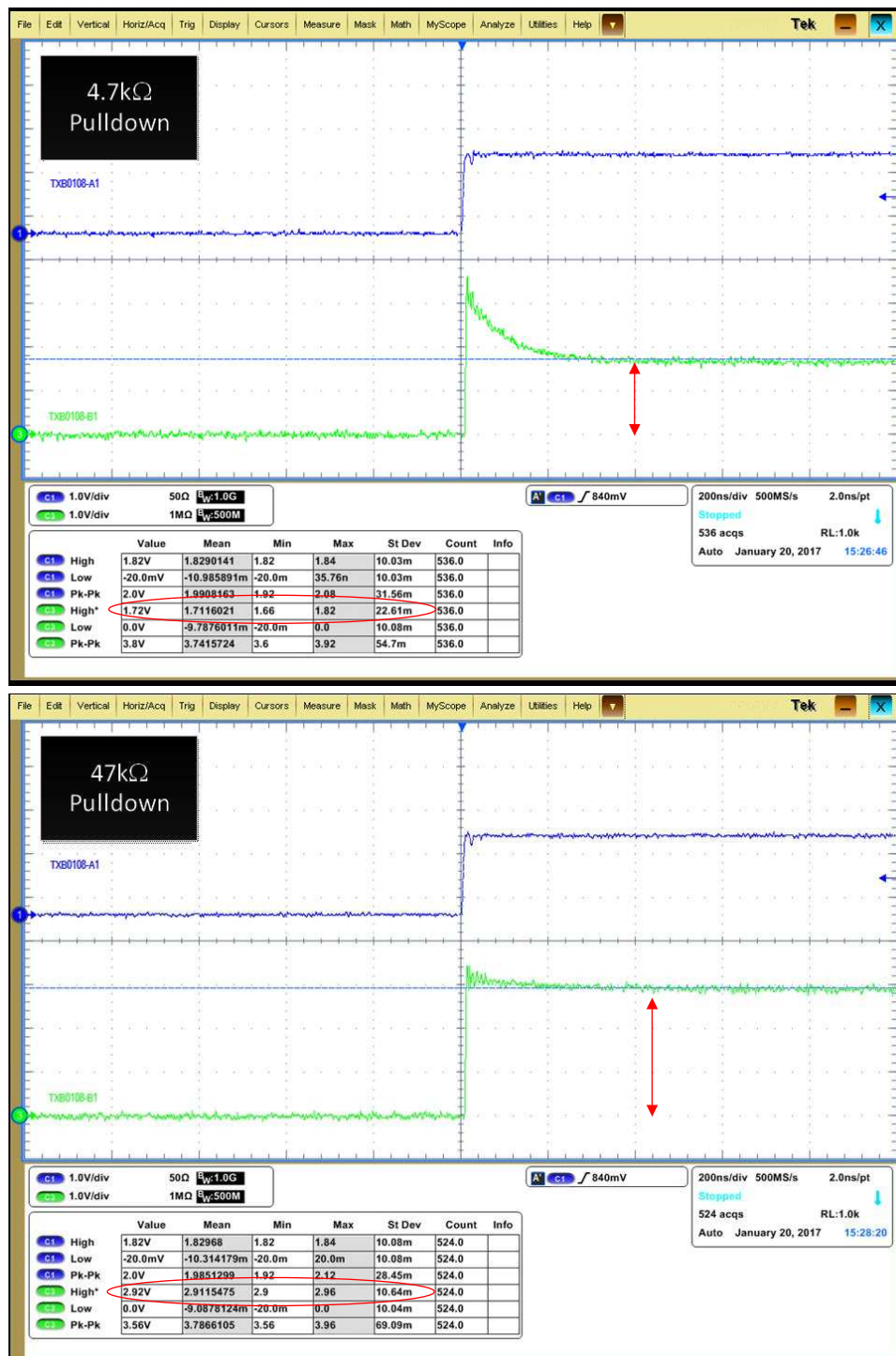


Figure 10. TXB0108 Pulldown Resistor Output

The results in Figure 10 illustrate the changes that pull-down 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 pull-down resistor. The negative impact of pull-down 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 <sub>OL</sub> (V)	V <sub>OH</sub> (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<sub>OL</sub> based on the pullup value.

$$V_{OL} = \frac{4 \text{ k}\Omega}{4 \text{ k}\Omega + R_{pu}} \times V_{CCO} \quad (2)$$

In Equation 2, substitute in the external pullup resistor value for R<sub>pu</sub> and the V<sub>CC</sub> voltage at the output port for V<sub>CCO</sub> to obtain the estimated V<sub>OL</sub> value.

Similarly, the resulting V<sub>OH</sub> value based on an external pulldown resistor can be estimated using Equation 3.

$$V_{OH} = \frac{R_{pd}}{R_{pd} + 4 \text{ k}\Omega} \times V_{CCO}$$

where

- R<sub>pd</sub> is the pulldown resistor value
- V<sub>CCO</sub> 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](#)

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