Comparison of Differential-Mode Noise Immunity of RS-485 Receivers With 3.3-V Supply

Clark Kinnaird

Industrial Interface

ABSTRACT

RS-485 is a widely used standard for industrial communication due to its simplicity and suitability for use in high-noise environments on long cables. Inherent in the standard are balanced signal drivers and receivers, which use differential signaling to reject common-mode noise. Receiver hysteresis is commonly used to ensure glitch-free reception even when differential noise is present. This application report compares the noise immunity of the SN65HVD37 to similar devices available from competitors.

Contents

1 Noise Immunity 1
2 Receiver Sensitivity and Hysteresis 2
3 The Effect of Cable Attenuation 2
4 Test Method for Noise Immunity Comparison 4
5 Noise Immunity Test Results 4
6 Comparison of Results 9

List of Figures

1 Receiver Hysteresis Improves Noise Immunity 2
2 Effect of Cable Attenuation Reduces the Received Transition Edges 3
3 Arrangement of Oscilloscope Plots in the Following Plots 4
4 Comparison of Receiver Response With 45-mVpp Noise 5
5 Comparison of Receiver Response With 60-mVpp Noise 6
6 Comparison of Receiver Response With 75-mVpp Noise 7
7 Comparison of Receiver Response With 90-mVpp Noise 8
8 Receiver Response With 100-mVpp Noise (SN65HVD37) 9

1 Noise Immunity

Noise immunity for this discussion is defined as the ability of a communication system to send and receive correct binary data in the presence of unwanted electrical noise. The noise source in any real application depends on the environment around the network. It may be due to power supplies, high-current machinery, radio-frequency coupling, or any number of other sources. See the TI application report SLLA057 *A Survey of Common-Mode Noise*. In most RS-485 (or similar RS-422 or CAN-based) systems, twisted-pair cables and balanced differential signaling are used to reduce the influence of external noise on the network signaling.

RS-485 is by nature of its balanced circuits and twisted-pair media, relatively immune to common-mode noise. However, conversion of common-mode noise to differential noise is possible in all real systems, due to unintended imbalances in the cabling, loading, and circuit parameters. Because common-mode noise is especially pervasive in industrial environments, some differential noise can be expected. Designers should consider immunity to differential noise as well as immunity to common-mode noise.

2 Receiver Sensitivity and Hysteresis

In order for a differential receiver to meet RS-485 requirements, it must compare the voltages on the A and B inputs, and output a specific logic state (conventionally a logic HIGH) if the differential voltage (V_A $–V_B$) is greater than +200 mV. This is defined as the ON (or binary 0) state by the RS-485 standard . The receiver must output the complementary state (conventionally a logic LOW) if the differential voltage is more negative than -200 mV. This is defined as the OFF (or binary 1) state by the RS-485 standard [(1)]. These requirements apply across a common-mode input range of –7 V to 12 V. The standard further suggests, but does not require, that receiver hysteresis be implemented to prevent “instability or oscillatory conditions in the receiver device”. Most manufacturers include receiver hysteresis in their RS-485 devices. The effect of receiver hysteresis is illustrated in Figure 1.

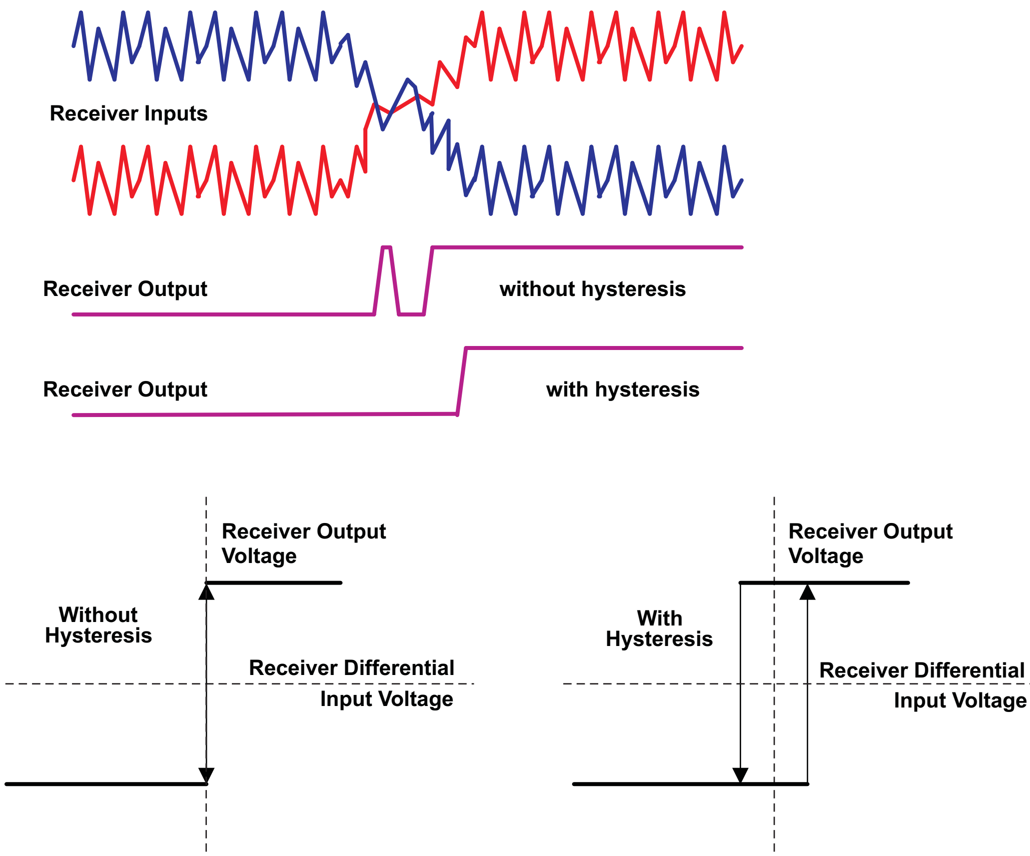


Figure 1. Receiver Hysteresis Improves Noise Immunity

3 The Effect of Cable Attenuation

Because RS-485 requires a relatively large signal at the driver outputs, with at least 3 V of separation between an ON signal (V_{DIFF} = 1.5 V) and an OFF signal (V_{DIFF} = –1.5 V), the effect of reasonable noise levels might not be expected to have an impact. However, it is informative to look at the actual signals involved, including the effect of the connecting cable.

Figure 2 shows a set of signals in various points through an RS-485 system. The top trace (white) is the data input to the driver, the D pin. The signal in this case is a 50% duty cycle square wave, with signaling rate of 250 kbps, or a bit time of 4 µs.

The second trace (green) is the differential signal from the driver outputs (the Y and Z pins in the case of the SN65HVD37). Note that the transitions are sharp, with little transition time between a low level and a high level. With amplitude of ±2 V, these levels are ten times higher than the ±200-mV receiver sensitivity levels required by RS-485, thereby having plenty of signal margin.

(1) ANSI/TIA/EIA-485-A Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems

The third trace (yellow) is the differential signal received at the inputs to the receiver (pins A and B on the SN65HVD37). This is after transmission through a 1500-meter cable. Certainly, this is an extreme example of cable length, but this case is used for illustration purposes. Note that the received differential signal has been reduced in amplitude due to losses through the copper. The transition edge rates have also been significantly reduced, making the signal look somewhat more like a sinusoid than a square wave. The differential signal takes longer to traverse the region between -200 mV and +200 mV, due to the reduced slope of the transition. In this transition zone, the signal is vulnerable to additive noise that can cause the total signal to randomly transition through the receiver thresholds, causing unexpected and undesirable *glitches* on the receiver output.

The fourth trace is the logic output of the receiver (the R pin). In this example, with no random additive noise, the receiver correctly transitions as expected.

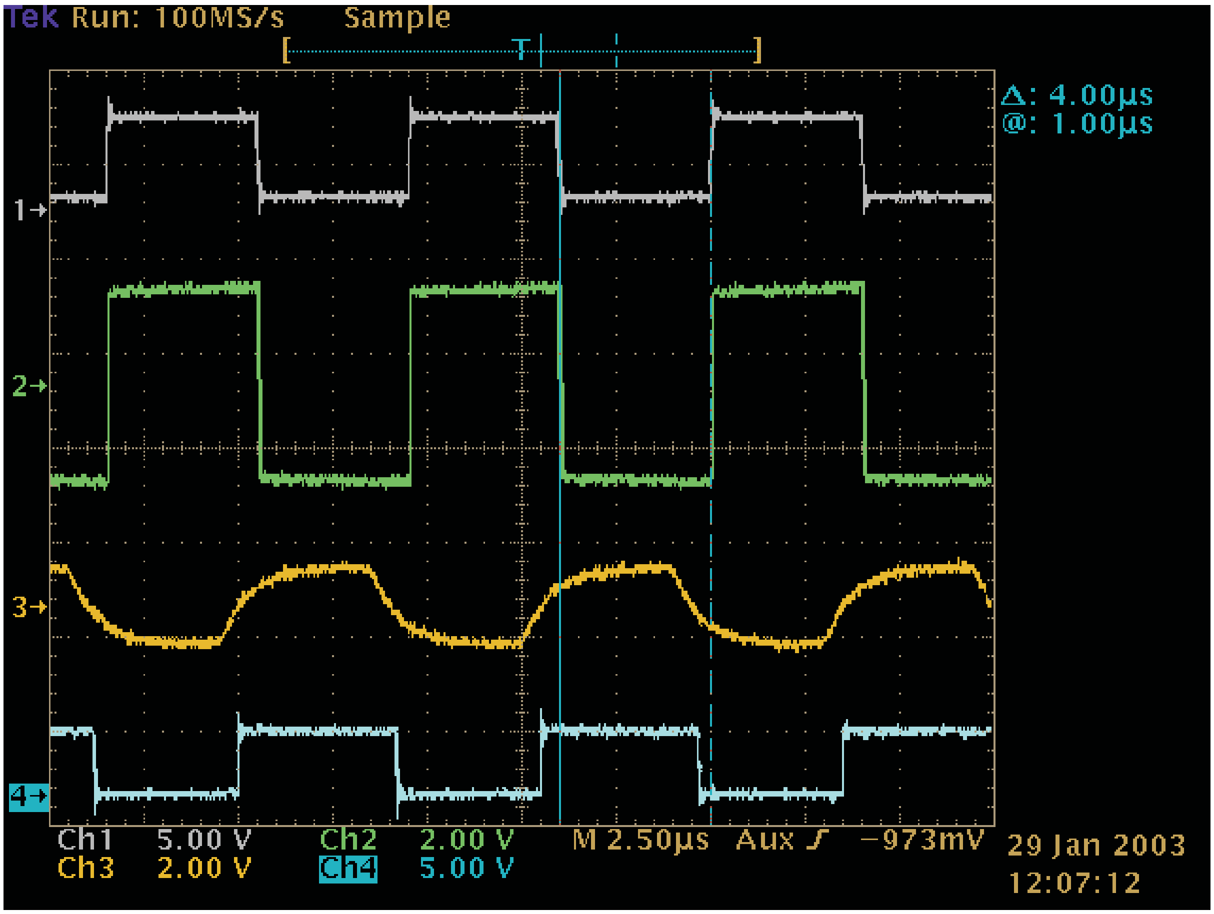


Figure 2. Effect of Cable Attenuation Reduces the Received Transition Edges

4 Test Method for Noise Immunity Comparison

In an ideal network, the differential signals at the receiver inputs instantaneously transition from one state to the other. As observed in Section 3, at points in the network close to the active driver, this is approximately true, with only a brief transition time depending on the output slew rate of the differential driver. However, at points in the network separated by long cable runs from the active driver, the properties of the cable (usually matched-impedance twisted-pair) attenuate the high-frequency components of the transitions, and tend to *round-off* the signal edges. If noise is then introduced on the signal lines, this can cause spurious transitions in the receiver output, which may then lead to communications errors or system faults.

In the following comparison, the input signal to the differential receiver is a sinusoid with a frequency of 1 kHz (signaling rate 2 kbps) and an amplitude of 700 mV peak-to-peak. All the comparison devices correctly respond when the amplitude of the signal exceeds the RS-485 thresholds of above +200 mV (HIGH) or below –200 mV (LOW). It is during the transition between the thresholds that the receiver is vulnerable to differential noise. A small-amplitude, higher-frequency voltage source is introduced as differential noise, and the resulting changes in the receiver output serve as a measure of the relative noise immunity of the differential receivers.

5 Noise Immunity Test Results

The noise immunity results for the SN65HVD37 and three competitive devices are shown and compared in Figure 3, with increasing levels of induced differential noise. In each figure, the test setup is unchanged between the comparison devices, so a relative comparison of noise immunity can be made.

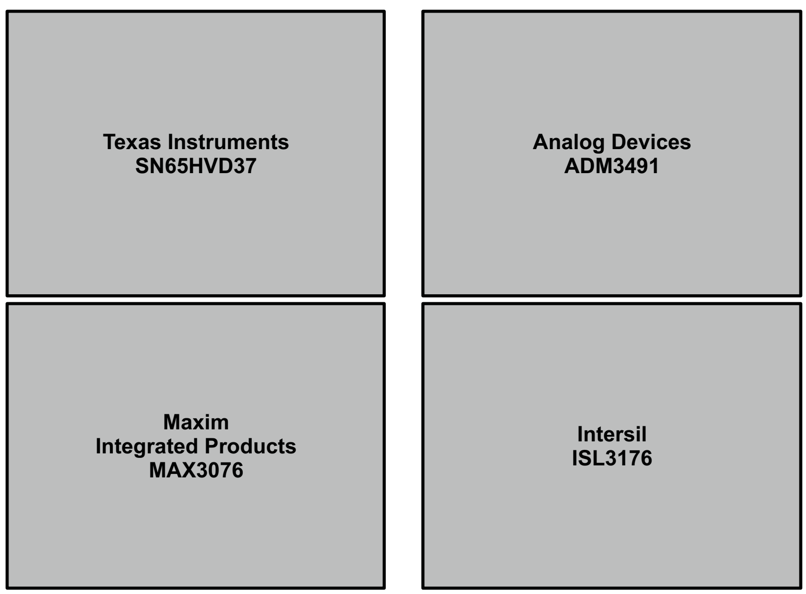
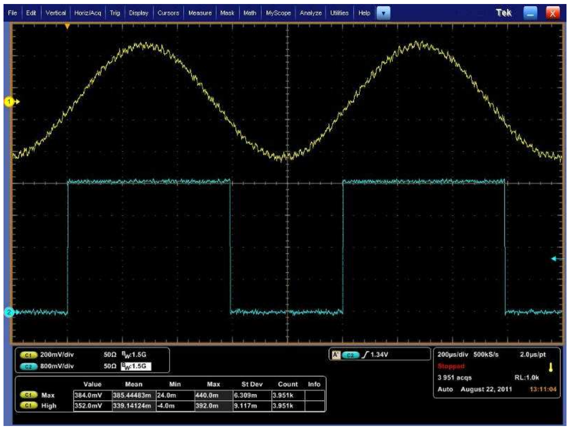
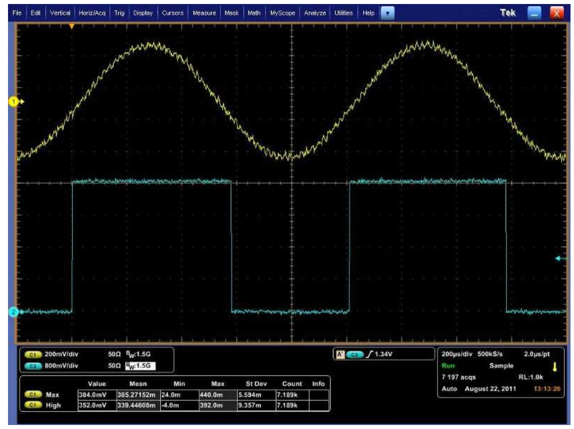


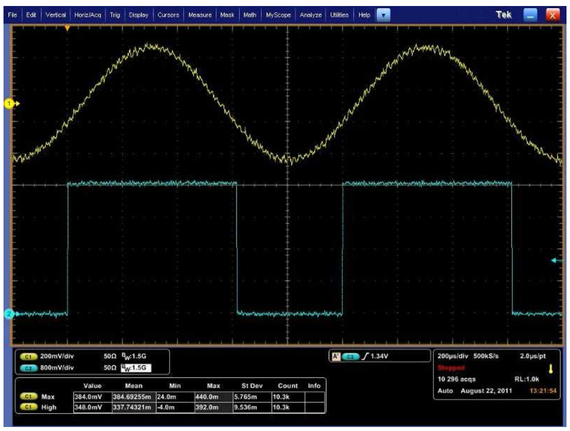
Figure 3. Arrangement of Oscilloscope Plots in the Following Plots



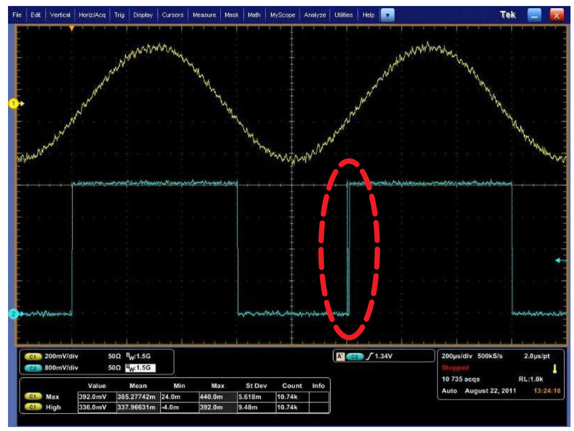
Texas Instruments
SN65HVD37



Analog Devices
ADM3491



Maxim
Integrated Products
MAX3076



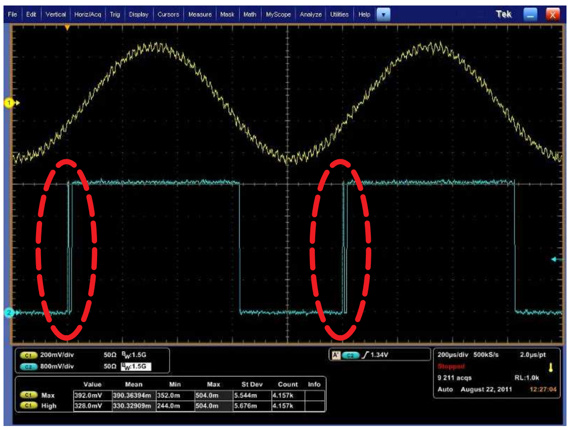
Intersil
ISL3176

Figure 4. Comparison of Receiver Response With 45-mVpp Noise

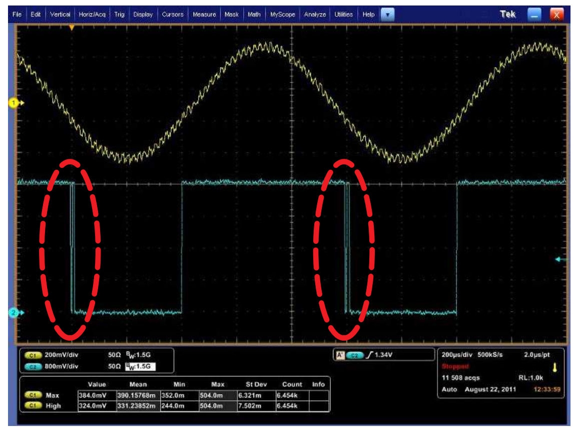
Figure 4 shows the response of all four devices to differential noise with a peak-to-peak amplitude of only 45 mV. Note that most of the devices properly switch only once as the primary signal transitions through the receiver threshold. However, the ISL3176 is seen to transition twice on one of the rising edges. This indicates that the positive-going threshold (V_{IT+}) was crossed and then the negative-going threshold (V_{IT-}) was crossed, due to the noise signal, when only a single transition is expected. The receiver quickly resumes the correct state as the primary signal amplitude exceeds the noise, but in some systems this *glitch* is interpreted as three bits, where only a single-bit state is intended. Note that the undesired transitions do not occur on every edge, so the sensitivity and hysteresis of the ISL3176 receiver is just at the boundary of this signal-to-noise condition.

Texas Instruments
SN65HVD37

Analog Devices
ADM3491



Maxim
Integrated Products
MAX3076



Intersil
ISL3176

Figure 5. Comparison of Receiver Response With 60-mVpp Noise

Figure 5 shows the response of all four devices to differential noise with a peak-to-peak amplitude of 60 mV. Note that at this level of noise, most of the devices are showing at least some double-switching as the primary signal transitions through the receiver threshold. This indicates that one of the receiver thresholds (V_{IT+} or V_{IT-}) was crossed and then the other threshold (V_{IT-} or V_{IT+}) was crossed, due to the noise signal, when only a single transition is expected.

The receiver quickly resumes the correct state as the primary signal amplitude exceeds the noise, but in some systems these *glitches* are interpreted as three bits, where only a single-bit state is intended. Note that the undesired transitions do not occur on every edge, so the sensitivity and hysteresis of these receivers are just at the boundary of this signal-to-noise condition.

The SN65HVD37 is still switching only once in this case, showing that the separation between the thresholds (V_{IT+} and V_{IT-}) is sufficient to make this device immune to 60-mV peak-to-peak noise.

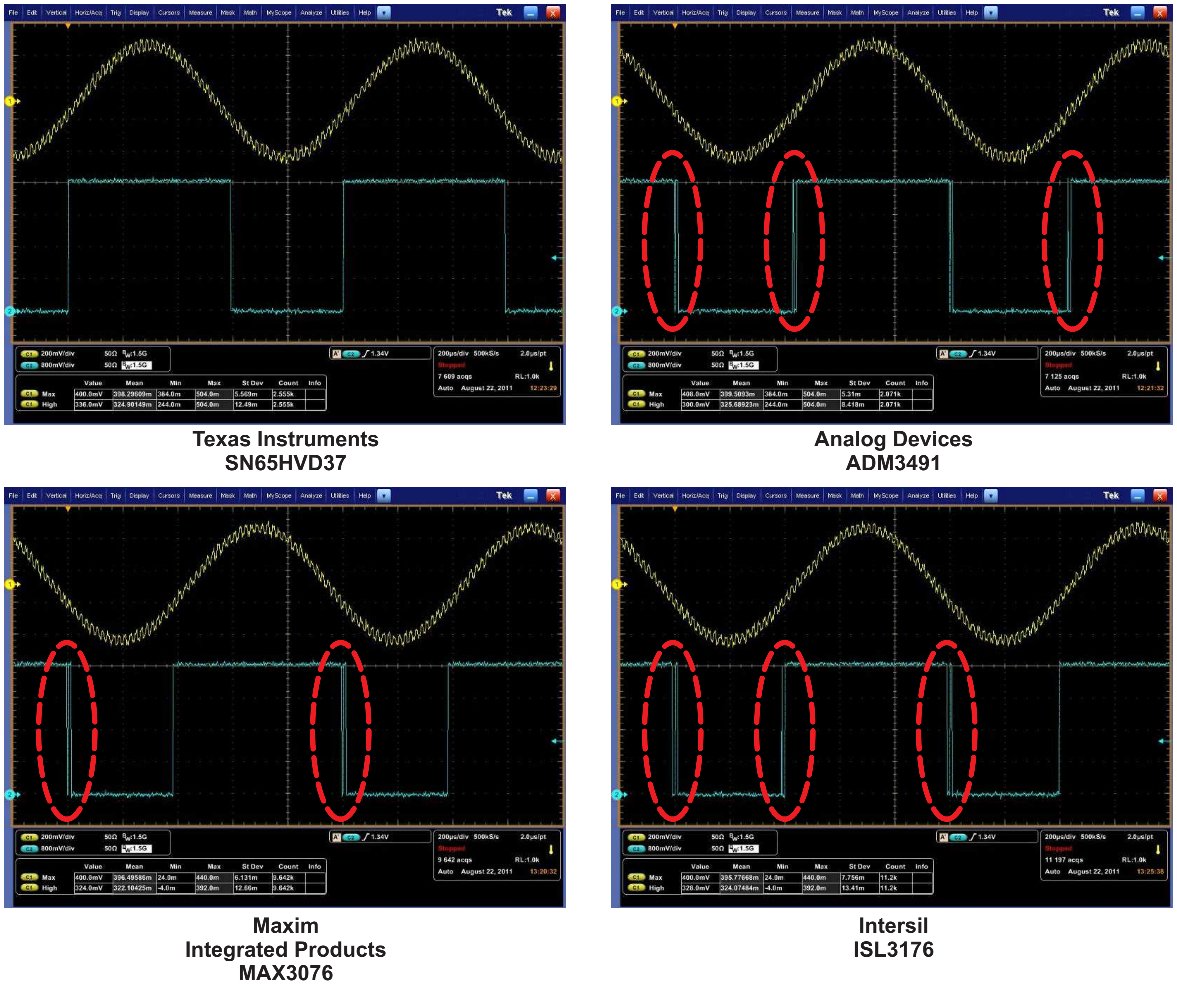
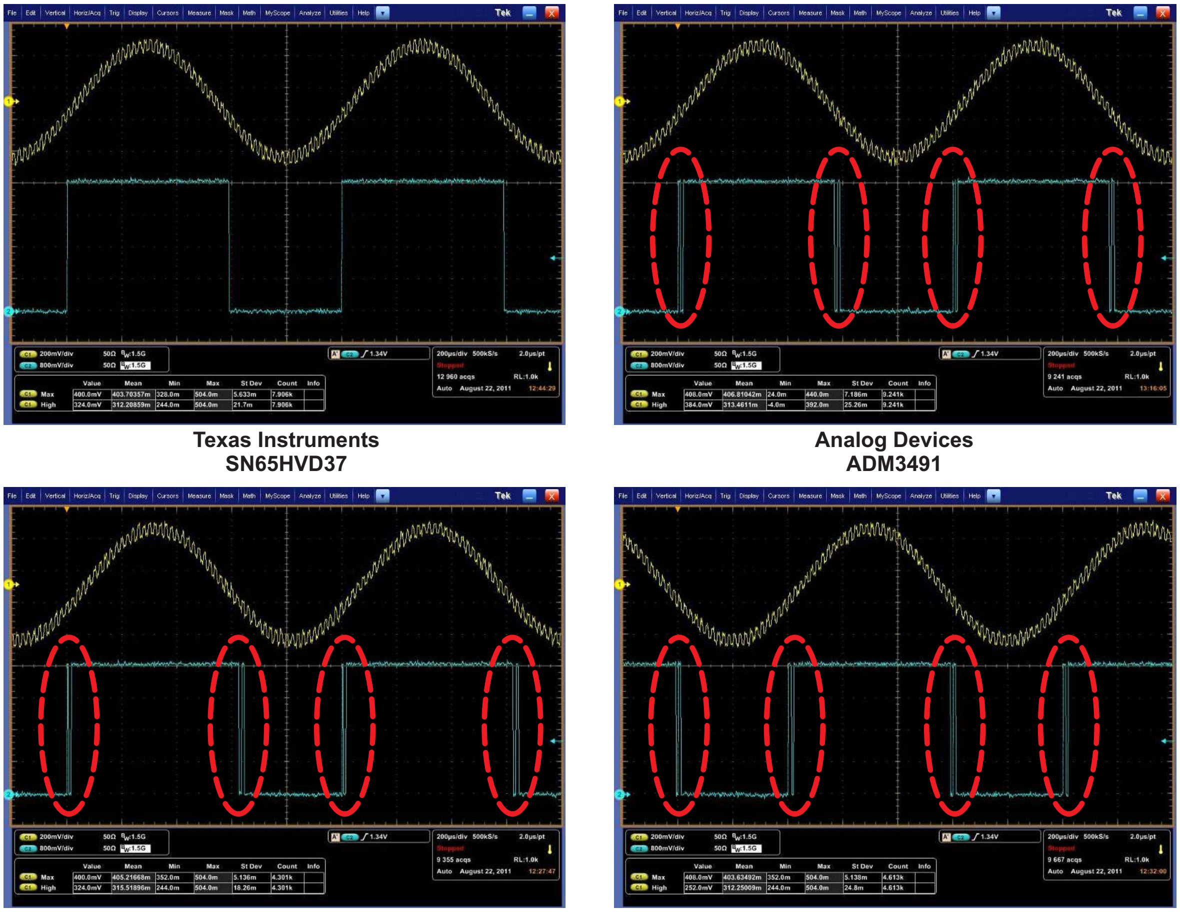


Figure 6. Comparison of Receiver Response With 75-mVpp Noise

Figure 6 shows the response of all four devices to differential noise with a peak-to-peak amplitude of 75 mV. Note that at this level of noise, most of the devices are again showing double-switching as the primary signal transitions through the receiver threshold. Note the increased tendency to double-switch on both rising and falling edges for most of the devices, showing that their noise immunity is less than 75 mV.

The SN65HVD37 is still switching only once in these conditions, showing that the separation between the thresholds (VIT+ and VIT-) is sufficient to make this device immune to 75-mV peak-to-peak noise.



Texas Instruments SN65HVD37

Analog Devices ADM3491

Maxim Integrated Products MAX3076

Intersil ISL3176

Figure 7. Comparison of Receiver Response With 90-mVpp Noise

Figure 7 shows the response of all four devices to differential noise with a peak-to-peak amplitude of 90 mV. Note that at this level of noise, all of the devices except the SN65HVD37 are showing double-switching as the primary signal transitions through the receiver threshold.

Note that with this level of noise, the non-TI devices are showing a double-switch on both rising and falling edges, showing that their noise immunity is definitely below 90 mV.

The SN65HVD37 is still switching only once in these conditions, showing that the separation between the thresholds (V_{IT+} and V_{IT-}) is sufficient to make this device immune to 90-mV peak-to-peak noise.

Finally, Figure 8 shows the response of the SN65HVD37 to differential noise with a peak-to-peak amplitude of 100 mV. Note that at this level of noise, the HVD37 receiver begins to exhibit double-switching, as the other receivers did at lower levels. As summarized in Section 6, this indicates noise immunity about twice that of the other comparable devices.

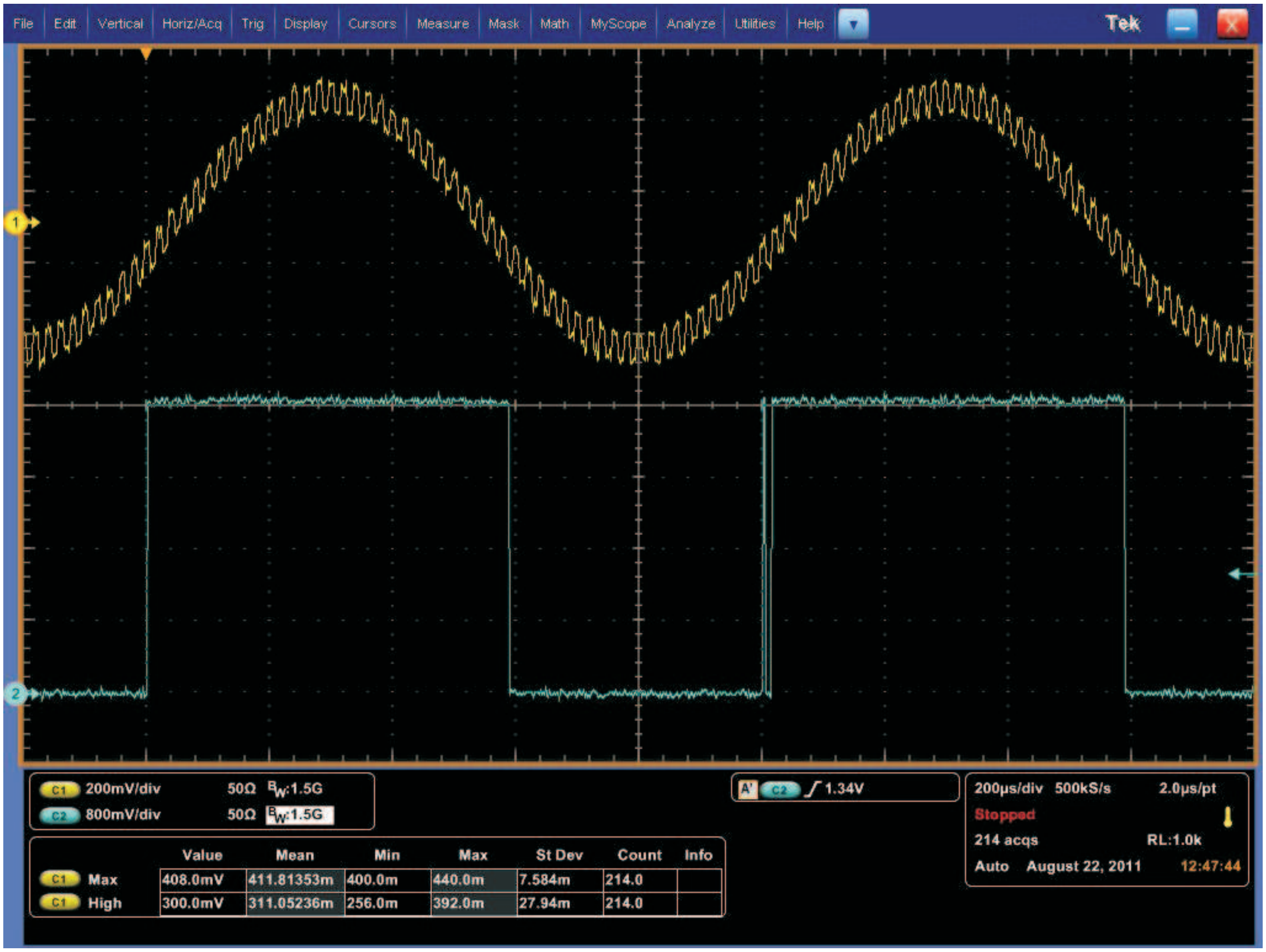


Figure 8. Receiver Response With 100-mVpp Noise (SN65HVD37)

6 Comparison of Results

Overall, the preceding figures demonstrate that the SN65HVD37 has higher immunity to noise than the comparison devices. Of course, several factors can affect the specific performance designers may see in their systems, such as the frequency of the noise, relative amplitude of signal and noise, external filtering, or external loading. But in general, the SN65HVD37 with industry-leading receiver hysteresis is a great choice for applications where noise immunity is important.

Noise	SN65HVD37	ADM3491	MAX3076	ISL3176
100 mV	√/ X	X	X	X
90 mV	√	X	X	X
75 mV	√	X	X	X
60 mV	√	X	X	X
45 mV	√	√	√	√ / X

√ = higher noise immunity
√/X = marginal noise immunity
X = poor noise immunity