

DS3662—The Bus Optimizer

National Semiconductor
Application Note 259
R. V. Balakrishnan
April 1981



DS3662—The Bus Optimizer

I. INTRODUCTION

A single ended Bus is an unbalanced Data Transmission medium, which is timeshared by several system elements. Like any unbalanced system, it is highly susceptible to common-mode noise, such as ground noise and crosstalk. In general, the latter determines the maximum physical length of the Bus that can be incorporated with acceptable reliability. Crosstalk is a major problem in high speed computer Buses which employ Schottky Transceivers for increased data rate capability. It is therefore highly desirable to minimize crosstalk noise in Bus circuits to allow for longer Buses and to provide higher system reliability.

This article describes the operation of the DS3662 Quad High Speed Trapezoidal Bus Transceiver, which has been specially designed to minimize crosstalk problems. The Driver generates precise Trapezoidal waveforms that reduce noise coupling to adjacent Bus channels. The Receiver uses a low pass filter, whose time constant is matched to the Driver slew rate to provide maximum noise rejection with acceptable signal delay characteristics. Precision high speed circuitry optimizes noise immunity without sacrificing the high data rate capability of Schottky Transceivers.

II. THE PROBLEM

Conventional Bus Drivers are designed to provide high output currents for charging and discharging relatively large Bus capacitances quickly. These high speed transitions are characterized by peak slew rates of up to 5V/ns around the mid-region of the transition. This can cause considerable noise coupling to adjacent lines, commonly referred to as

crosstalk. Crosstalk also includes noise induced by sources external to the Bus. Additional noise may be generated due to reflections at imperfect terminations.

Bus Receivers are designed to respond to high speed transitions and to provide low propagation delays. Unfortunately, their fast response results in high noise sensitivity. The combined effect of the noise on the Bus and the sensitivity of the Receiver to the noise severely limits the Bus performance.

III. THE SOLUTION

The above situation can be considerably improved by employing noise reduction techniques in both the Driver and the Receiver circuits. Slew rate control can be used in the Driver to reduce crosstalk, and Receiver noise sensitivity can be reduced by using a low pass filter at its input. These techniques are commonly used in line transmission circuits where the associated data rates in general are considerably lower. However, these techniques do present some difficulties in high speed Bus circuits. Increased rise and fall times, resulting from slew rate control, can affect data rates unless care is taken to limit the maximum rise and fall times to minimum pulse width requirements. With any appreciable slew rate control, the rise and fall times of the resulting Driver output waveform will be comparable to the pulse widths at maximum data rates. This condition dictates high fidelity of the transmitted waveform and precise Receiver thresholds at the middle of the Bus voltage swing in order to minimize pulse width distortion. Figure 1 illustrates the different sources of pulse width distortion due to the trapezoidal nature of the signal.

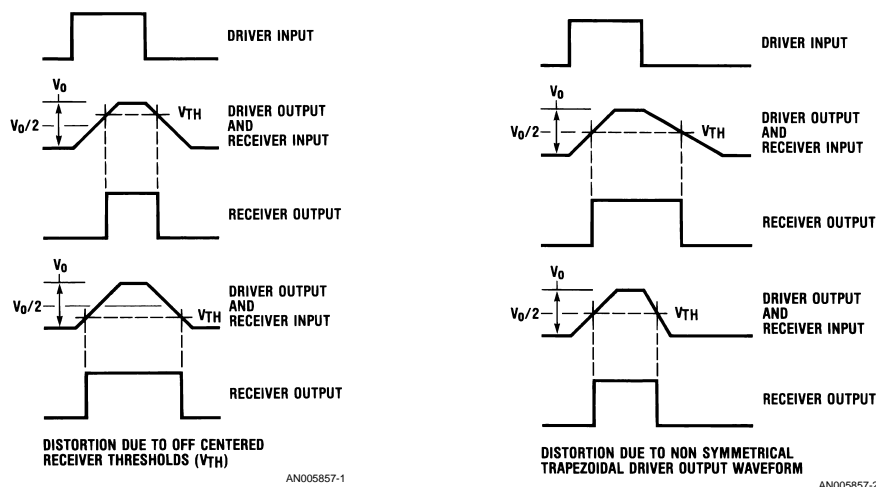


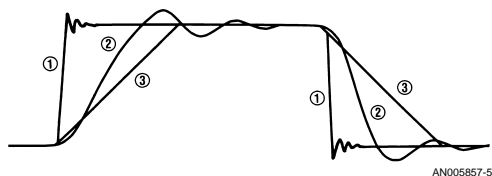
FIGURE 1. Pulse Width Distortion

The low pass filter in the Receiver should provide optimum noise rejection without introducing excessive delay in passing the signal waveform. In addition, the Receiver should have a symmetrical response to positive and negative going

transitions in order to maintain a low level of pulse width distortion, as well as equal noise rejection to positive and negative going noise pulses. The response of an ideal low pass filter to signal and noise pulses is shown in Figure 2.

AN-259

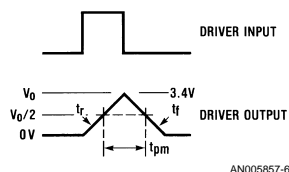
The DS3662 overcomes these and other problems by using high speed linear circuitry with on-chip capacitors for controlling slew rate and low pass filtering. The Driver is of open collector type intended for use with terminated 120 Ω Buses. The external termination consists of a 180 Ω resistor from the



1 — Typical High Speed Driver Output Unloaded
2 — Typical High Speed Driver Output Loaded
3 — Typical Output of Controlled Slew Rate Driver Which is Load Independent

Note: The word "loading" here refers to capacitive loading only.

FIGURE 4. Waveform Comparison



$t_{pm} = 20 \text{ ns}$
 $t_r = t_f = 15 \text{ ns}$
(10% to 90%)

FIGURE 5. Minimum Pulse Width Driver Output

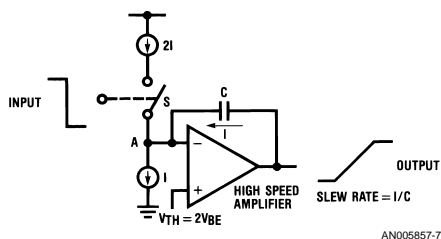


FIGURE 6. Driver

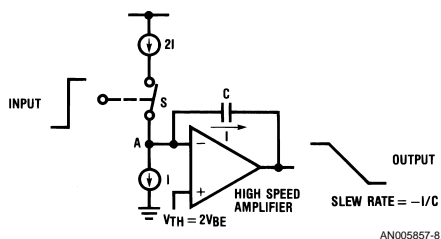


FIGURE 7. Driver

Likewise, when a low to high transition is applied to the input, switch "S" closes and node "A" is pulled up by the "21" current source, switching the amplifier output to a low state. The capacitor now has an equal but opposite charging current which once again limits the slew rate to $-1/C$ volts/sec. The

inherent tracking ability of I.C. current sources provide equal rise and fall times resulting in a symmetrical output waveform.

The on-chip capacitors are fabricated using back to back junction diodes. The use of junction capacitors reduces die area and the back to back connection allows operation with either polarity. The capacitor terminal, connected to the amplifier input, remains at $V_{th} \approx 1.6V$ during the output transition. This voltage, being close to the middle of the output swing, reduces the effect of the capacitor voltage sensitivity on the output waveshape.

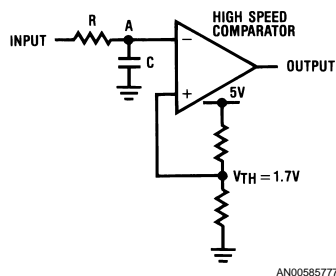
V. THE RECEIVER

The Receiver consists of a low pass filter followed by a high speed comparator with a typical threshold of 1.7V (see Figure 8). This threshold value corresponds to the mid-point voltage of the 0 to 3.4V Bus swing. It is derived from a potential divider allowing the Bus logic levels to track with V_{CC} variations. If the low pass filter capacitor is voltage insensitive, this circuit will provide equal propagation delay for positive and negative going signal transitions on the Bus. In addition, it will also provide equal noise rejection to a positive and negative going pulse (see Figure 2). However, the junction capacitors, being voltage sensitive, will exhibit non-symmetrical response in the above circuit. This problem is overcome in the DS3662 Receiver by using a back to back junction capacitor with the ground end biased at 1.7V (see Figure 9). Although the capacitor still varies with the voltage at node 'A', the variation is symmetrical about 1.7V (the middle of the Bus swing) and therefore will provide an identical response to transitions of either polarity.

VI. TRANSCEIVER PERFORMANCE

The characteristics of the trapezoidal Transceiver are fully detailed in the device data sheet. Some of the more important specifications are discussed below. Both AC and DC specifications are guaranteed over a 0–70°C temperature range and a supply range of 4.75–5.25V.

The Driver typically has a propagation delay of 15 ns with a maximum of 30 ns. The Receiver propagation delays are specified at 25 ns typical and 40 ns maximum. The Driver output rise and fall times are guaranteed to be within 10 to 20 ns with a typical of 15 ns. The noise immunity of the Receiver is specified in terms of the width of a 2.5V pulse that is guaranteed to be rejected by the Receiver (see Figure 10). The Receiver typically rejects a 20 ns pulse going positive from ground level or going negative from a 3.4V logic 1 level. Worst case rejection is specified at 10 ns.



The AC response of the DS3662 Driver and Receiver are depicted in *Figure 11* and *Figure 12* respectively. *Figure 11* shows the typical Driver output waveform as compared to a standard high speed Transceiver output. Oscillograms in *Figure 12* demonstrate the ability of the Receiver to distinguish the trapezoidal signal from the noise. Here the Receiver rejects a noise pulse of 19 ns width, while accepting a narrower signal pulse (= 16 ns) of the same amplitude (The signal is triangular since the pulse width is smaller than the rise and fall time of the Trapezoidal Driver output).

The performance of the Transceiver under actual operating condition is demonstrated in *Figure 13* through *Figure 15*. Oscillograms in *Figure 13* clearly show the capability of the DS3662 in real life situations. Here it is compared with the DS8834 under identical conditions. The Transceivers drive a minicomputer Bus (flat ribbon cable) 100 feet long, terminated at the far end with taps at various lengths for connecting to the Receiver input. The cable is randomly folded to generate crosstalk between the various parts. In addition a noise pulse is induced on the signal line by driving an adjacent line with a pulse generator. This corresponds to the second dominant pulse in the Bus waveforms at approximately 600 ns from the main signal pulse. As can be seen, the DS8834 with fast rise and fall times on the Driver output generates more crosstalk and its Receiver easily responds to this crosstalk and to the externally induced noise (even though it has hysteresis!), limiting the useful Bus length to

less than 10 feet. In contrast, the DS3662's Driver generates much less crosstalk and its Receiver is immune to the induced noise even when the noise amplitude exceeds the signal amplitude as seen in the oscillogram at 50 feet. When the same experiment was repeated with the DS8641, it responded to the noise even at 10 feet as shown in *Figure 14*.

Figure 15 shows the plots of maximum data rate versus line length for the three Transceivers discussed above under two different conditions. The graph in *Figure 15* is obtained with no consideration to the pulse width distortion whereas the one in *Figure 15* is obtained for a maximum allowable pulse width distortion of $\pm 10\%$. A square waveform is used so that the pulse width distortion criteria will apply to both positive and negative going pulses. These graphs clearly show that the DS3662 can be used at considerably higher data rates with lower distortion for longer distances than the other two Transceivers (*Figure 15*) although the others have a slightly higher data rate capability at short distances with high timing distortion (*Figure 15*).

VII. CONCLUSION

The DS3662, with its combination of a trapezoidal Driver and a noise rejecting Receiver utilizing on chip capacitors, represents a significant improvement in high speed Bus circuits and a solution to Bus noise problems commonly encountered in Mini and Microcomputer systems.

Typical High Speed Bus Driver Output Waveforms DS3662—Trapezoidal Driver Output Waveform

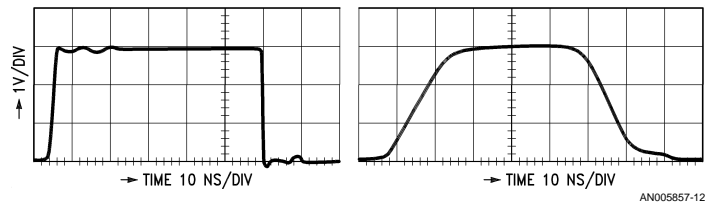


FIGURE 11.

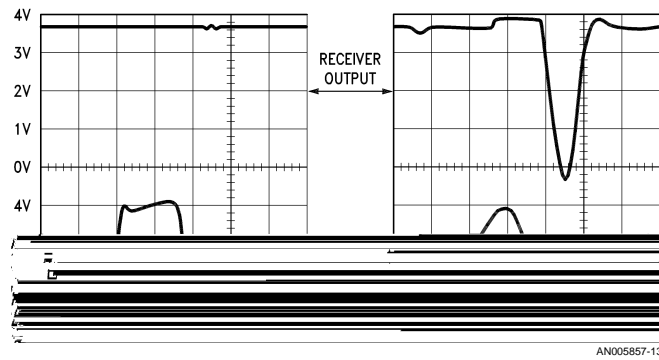


FIGURE 12. DS3662 Receiver Response

DS8834 DS3662

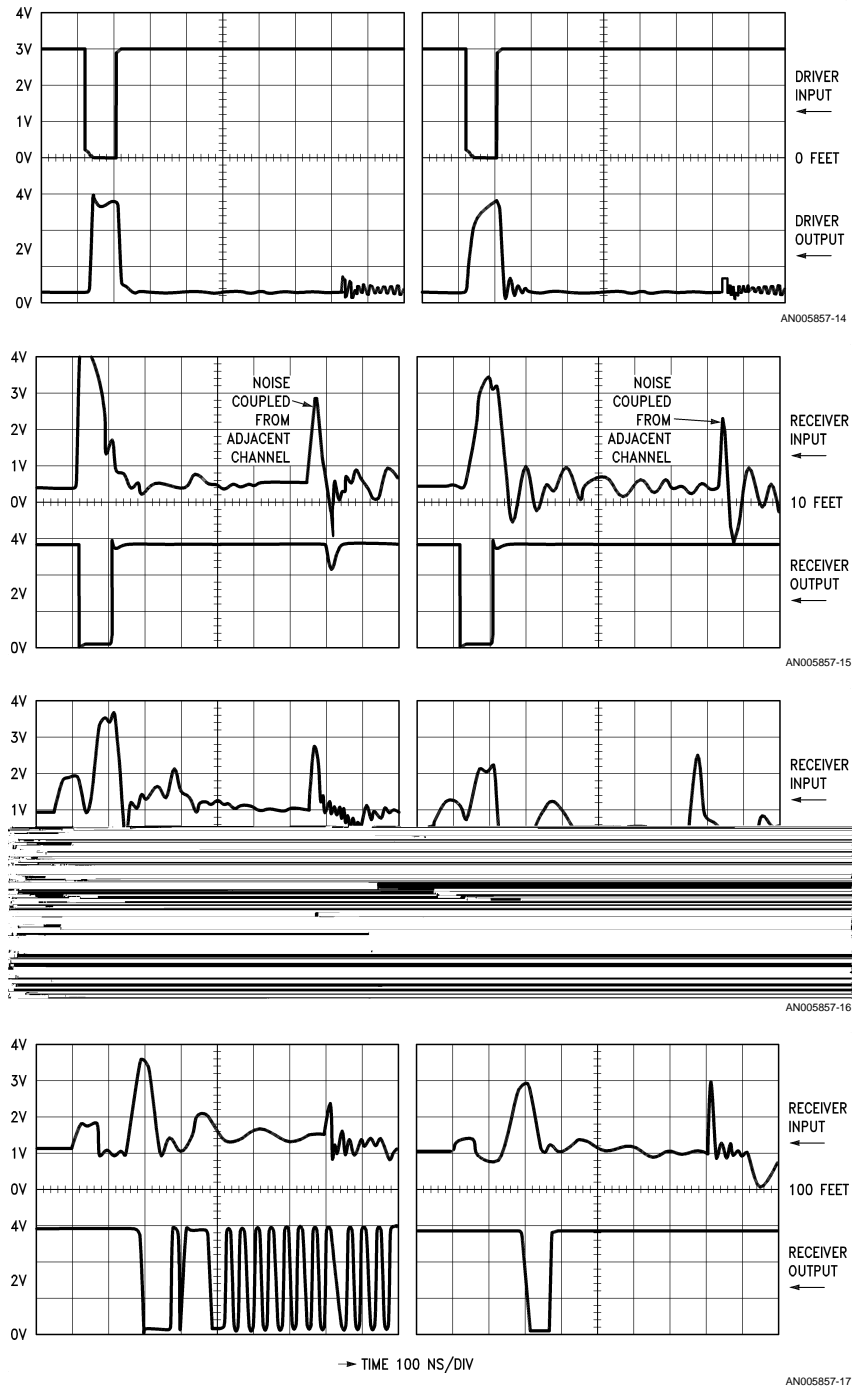
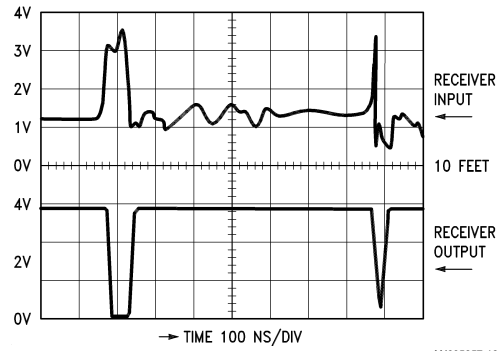


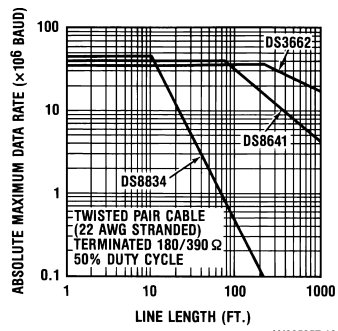
FIGURE 13.

DS8641

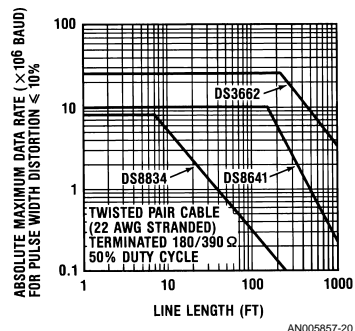


AN005857-18

FIGURE 14.



AN005857-19



AN005857-20

FIGURE 15. Data Rate vs. Line Length

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



National Semiconductor Corporation
Americas
Tel: 1-800-272-9959
Fax: 1-800-737-7018
Email: support@nsc.com

www.national.com

National Semiconductor Europe
Fax: +49 (0) 1 80-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 1 80-530 85 85
English Tel: +49 (0) 1 80-532 78 32
Français Tel: +49 (0) 1 80-532 93 58
Italiano Tel: +49 (0) 1 80-534 16 80

National Semiconductor Asia Pacific Customer Response Group
Tel: 65-2544466
Fax: 65-2504466
Email: sea.support@nsc.com

National Semiconductor Japan Ltd.
Tel: 81-3-5639-7560
Fax: 81-3-5639-7507