Application Note

RS-485: What is Auto-Direction and Why it is Useful in Systems?

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ABSTRACT

The RS-485 auto direction feature is discussed and lab tested using THVD14x6 devices. Layout example for co-layout of VSSOP (DGK) and SOT (DRL) packages is shown.

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Trademarks

1 Enable Pins and Auto-Direction

The RS-485 interface works using differential signaling that is effective in rejecting common-mode noise making it a popular choice for long-distance communication. In applications, the enable pins of RS-485 transceivers are usually connected to general purpose input output (GPIO) of microcontrollers. For example, in a common 8-pin half-duplex RS-485 transceiver shown in Figure 1-1, the driver enable (active high) is pin 3 (DE), while the receiver enable (active low) is pin 2 (REB). The auto direction feature reduces the reliance on separate pins for driver-enable and the receiver-enable functionality.

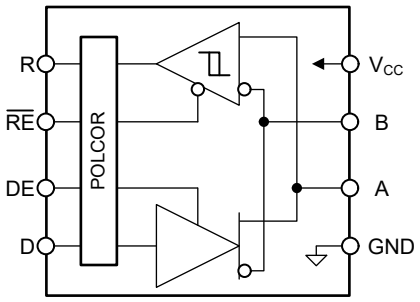

Figure 1-1. Pinout of 8-pin RS-485 Transceiver

In applications, regular RS-485 drivers or receivers can be controlled by a microcontroller separately with 2 GPIO pins or with 1 GPIO pin if the DE pin and REB pin are shortened. Similarly, if a digital isolator is used for these logic controls, two isolation channels are needed for the DE and REB pin or one isolation channel is needed for the combined DE and REB control pins. To further reduce the number of GPIO pins for logic control or the number of isolation channels needed, the THVD14x6 (THVD1406 and THVD1426) devices can be used. These parts are half-duplex RS-485 transceivers with the auto direction control feature which do not include enable pins like DE and REB as shown in Figure 1-2. Instead, these devices use the data input pin (D pin) to initiate communication. Logic control happens automatically meaning software to support the enable controls are no longer required.

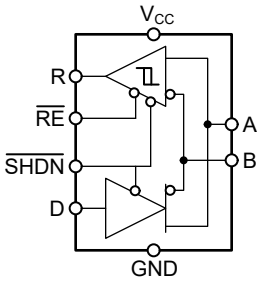

Figure 1-2. Pinout of THVD14x6

Installed in a system and powered on, THVD14x6 enters the receiver mode by default. When an input signal at the D pin (pin 4) toggles from high to low, the driver is triggered to be active and starts sending data. In RS-485 communication systems, universal asynchronous receiver-transmitter (UART) protocol is widely used. In this protocol, all data is transferred bit by bit, while the last bit is a stop bit which is normally high and the line idles as a logic high afterwords. As the THVD14x6's input pin is pulled high for a certain time ($t_{device\_autodir}$), the driver becomes disabled and releases the bus. The driver active time is 0.8-µs in THVD1426 and 8-µs in THVD1406.

In this application note, several test cases are presented with various system configurations. The information presented can help a system designer understand how the auto direction feature of half duplex RS-485 devices work and aid to build successful systems with devices such as THVD14x6.

2 Test Setup

In all the tests, TTL-232R cables from Future Technology Devices International Ltd are used to create the communication link from the PC to the RS-485 evaluation boards (EVM) by converting the USB signal to a UART signal. The communication data is generated by a third-party software (Serial Port Utility) on the PC, which follows the UART protocol with various baud rates. Figure 2-1 shows an example of the UART configuration for 115200 baud rate with a byte format of 8 data bits and 1 stop bit.

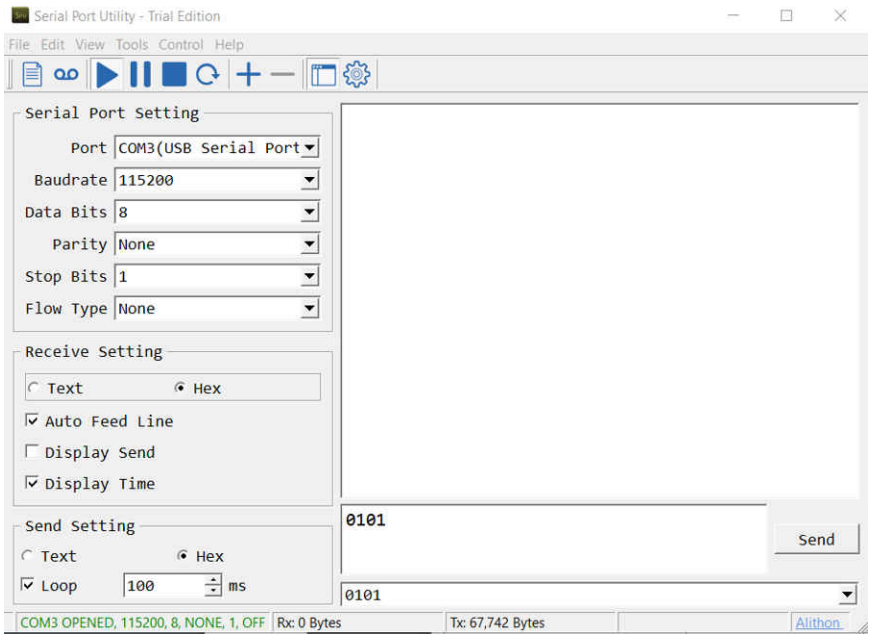

Figure 2-1. Serial Port Utility GUI

2.1 Test One: Auto Direction in Action

In the first test, one general purpose half-duplex RS-485 EVM is used with a THVD1426 device populated. The board is terminated with 120-Ω resistor and powered by 3.3-V. By setting the $\overline{\text{SHDN}}$ pin (pin 2) high and the REB pin (pin 3) low, the device is active and the receiver is always on. A string *0x0101h* in hexadecimal format with 2,000,000 baud rate is chosen to be transmitted. In measurement, three locations are probed on the board - input data (pin 4), bus pins (pin 6 and 7), and received data (pin 1). In Figure 2-2, channel 1 is input data with the label *TX*, while channel 2 is output data labeled *RX*. The bus signal *VOD* (channel 4) is taken by a differential probe. These test results show that the driver is turned on as the input signal toggles from high to low. After transmission finishes, the driver releases the bus. The bus becomes high impedance and the bus voltage is pulled together by termination

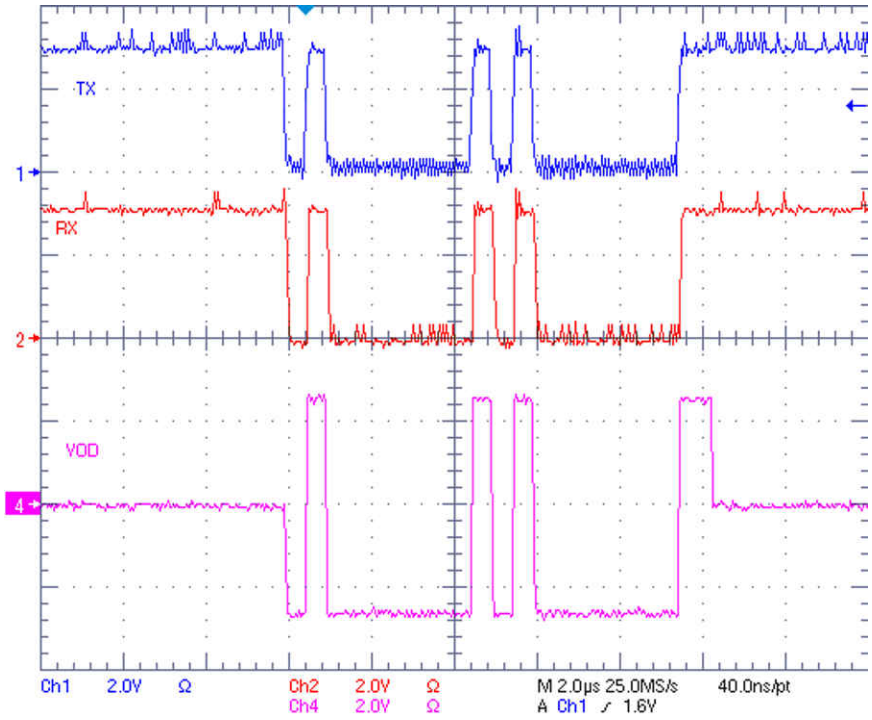

Figure 2-2. Auto Direction Test of THVD1426

2.2 Test Two: Sending Data Below Recommended Operating Conditions

In the second test, with identical hardware setup as the first one, the same string is sent with the baud rate at 115200, which is considerably lower than THVD1426's recommended operating condition (12 Mbps). The purpose of this test is to check if THVD14x6 works at a data rate lower than the recommendation in the data sheet. One bit width (8.6-µs) of input data is much longer than the maximum active time of the driver (1.45-µs). As the waveforms of the last bit in previous test show, the differential bus voltage becomes 0-V as the driver finishes its active time shown in Figure 2-3. Therefore each *1* bit input shows a spike on bus before settling to 0-V. Given that the receiver threshold Vth+ is -20-mV, this 0-V generates a high at receiver output. Therefore, correct bits are still produced by the receiver. In system design, it might be a good idea to add some pull-up resistors on the A side and pull-down resistors on the B side. These bias resistors would generate a constant voltage higher than 0-V on the idle bus for better noise immunity. For details about how to choose resistor values refer to the RS-485: Passive Failsafe for an Idle Bus article.

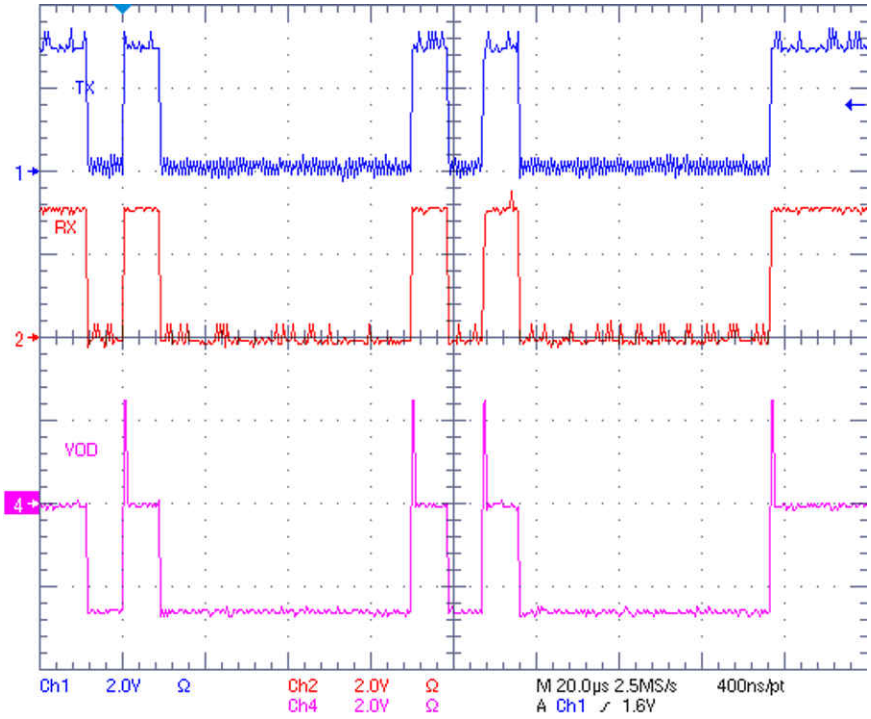

Figure 2-3. Auto Direction Test of THVD1426 with Low Data Rate

2.3 Test Three: A System With No Termination

The third test follows the same procedure with the same data rate except the board is no longer terminated. In some applications where the data rate is low and the distance is short, the signal integrity can still be within acceptable margins without termination in the system. Other than saving power, sparing termination also makes implementation easier since all nodes can be treated equally. It is observed from the results as shown in Figure 2-4 that the bus amplitude is larger due to lighter bus load, while the bus discharge time is much longer than what is observed in the second test. The reason is that the bus impedance is much higher than 120-Ω when the termination is removed. Therefore, the RC decay with the disabled driver is much larger. Please note that the different discharge time does not affect the communication. Of course, results can vary if the bus load is larger or data rate is faster.

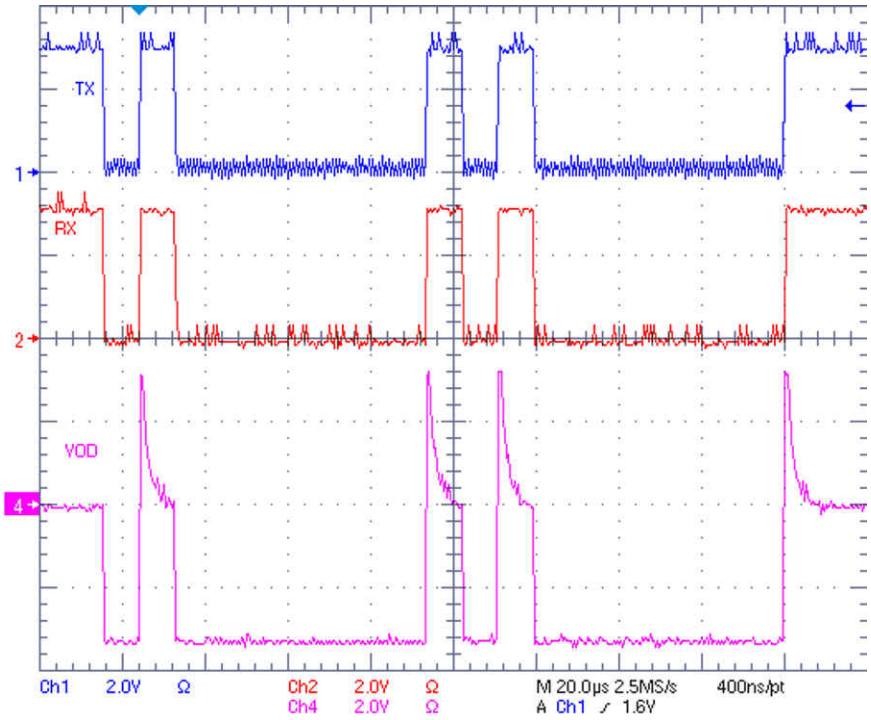

Figure 2-4. Auto Direction Test of THVD1426 with Low Data Rate and No Termination

2.4 Test Four: A System With a Fully Loaded Bus

Based on these two previous tests, two EVMs and 300-ft AWG 22 cables are used to test long-distance communication with the same low baud rate 115200. As before, the $\overline{SHDN}$ pin (pin 2) is set to a logic high and the REB pin (pin 3) set to a logic low on both the leader and follower nodes. In this test, the data is transmitted by the leader node at the D pin and is received by the follower node at the R pin. Generally, in systems with long cables, the transmission line effects need to be considered. Termination resistors are always recommended on boards for better signal integrity. This test is no exception. To mimic the load of multiple nodes, 375-Ω resistors are inserted from the bus to ground as shown in Figure 2-5. In the real world, the common mode node of the load could have some potential shift other than ground. Each input of THVD14x6 has about 96-kΩ impedance. The 375-Ω lumped resistor represents about 256 nodes.

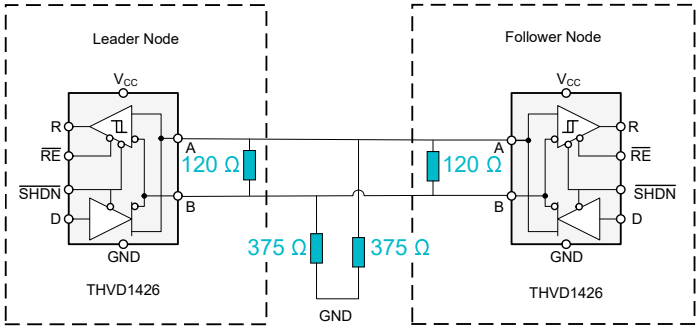

Figure 2-5. Auto Direction Test of THVD1426 with a Fully Loaded Bus

In the waveforms of Figure 2-6, TX (channel 1) is the input at the D pin of the leader node, the receiver output waveform (channel 2) and bus signal waveform (channel 4) are taken on the board of the follower node. The measured results show that bus signal is attenuated due to cable loss, while the shape of bus signal is kept similar to the one shown in Figure 2-5. Like the results of the second test, no issues were found in the communication. The same comments also apply to this setup - adding some bus bias network would make the communication more robust.

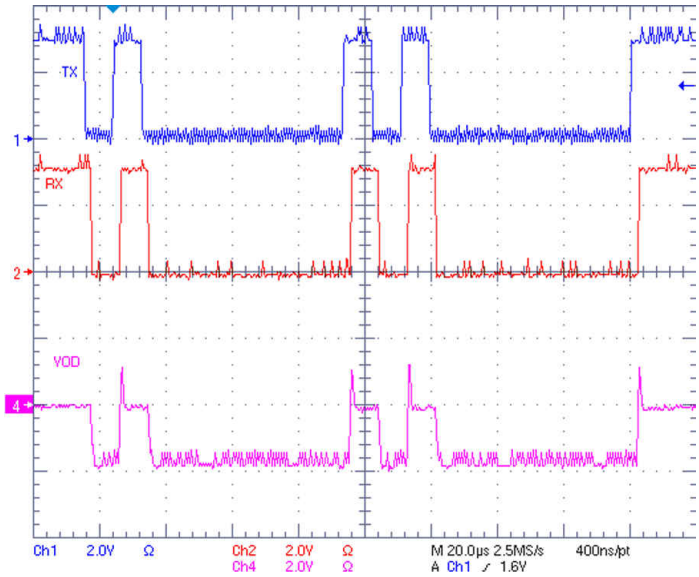

Figure 2-6. Test Results of 115.2-kbps 300-ft Transmission with a Fully Loaded Bus

3 Layout and Package Options

In system design, it would be nice to have flexibility of sharing different footprints on the same board. The THVD14x6 family come in two packages – SOIC (D) and SOT (DRL). An example of co-layout of these two packages is presented in Figure 10-2 in the data sheet of THVD14x6. For small footprints, VSSOP (DGK) is another popular choice instead SOIC. For example, THVD2450, THVD1550, and THVD1450 all have the VSSOP option besides SOIC. Similarly, two small packages VSSOP and SOT can be put on the same board with little layout effort as shown in Figure 3-1. This co-layout footprint can be considered for space limited boards.

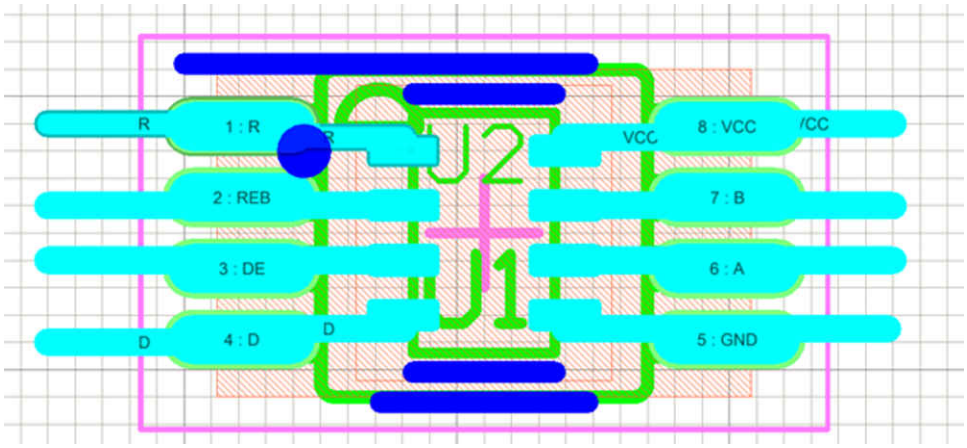

Figure 3-1. Layout Example for Co-layout of VSSOP (DGK) and SOT (DRL) Packages

4 Summary

In summary, other than the recommended operating condition, the THVD14x6 devices also works with lower data rates with no issues. The devices are flexible in the system configuration, working with various cable lengths, node numbers, and bus bias networks. The auto direction feature makes THVD14x6 a good choice when the system has limited isolation channels or GPIO pins.

5 References

- Texas Instruments, *RS-485: Passive Failsafe for an Idle Bus* Analog Applications Journal.
- Texas Instruments, *THVD1406, THVD1426 3.3-V to 5-V RS-485 Transceivers with Auto-direction Control and ±12-kV IEC ESD Protection* data sheet.

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