Application Note

How to Apply THVD8000 in Star-Network Systems

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ABSTRACT

Several tests with THVD8000 are presented for star network systems. The data shows that terminating every stub of non-daisy chain network can greatly improve signal integrity, which could lead to expanding the use cases of RS-485 systems. To work with terminated multiple-node network, high-speed amplifiers can be used as line drivers for power line communication applications to drive low-impedance loads.

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1 Introduction

THVD8000 and THVD8010 are transceivers for power line communication (PLC) applications. The built-in on-off key (OOK) modulation and demodulation cells enable communication data to be transmitted over a decoupling capacitor on power cables. The detailed discussion about system design is documented in the THVD800 Design Guide application note. These two devices utilize RS-485 physical layer signaling to achieve good common-mode immunity for long distance communication.

Like the RS-485 systems, daisy chain is the preferred topology for this power line communication system with termination at the two furthest ends. Without termination, open ends could generate reflections and create signal integrity issues. In some low data rate applications, the signal might have enough time to settle within one bit width. However, designers might find it is hard to apply THVD8000 and THVD8010 in other network topologies than the daisy chain. In this application note, some techniques are proposed as potential solutions for different bus topologies, and lab measurement data is presented for discussion.

2 Tests and Setup

2.1 Test 1: 4-Node Star Network Test

The experiments start with a 4-node star network. The system setup is composed of 4 nodes with Cat 5e unshielded cable. The segment of cable length is set as in Figure 2-1. Except a short cable (50-ft) connecting to Node 1, three other nodes are forked with long cables (500-ft and 700-ft). In each node, a THVD8000 evaluation board (EVM) is powered with 3.3-V supply. All EVMs are configured at the 5-MHz carrier frequency by setting a 1.5-kΩ pull-down resistor at R_{F_SET} (pin 3). Please note that all nodes are not terminated in this test for checking signal integrity.

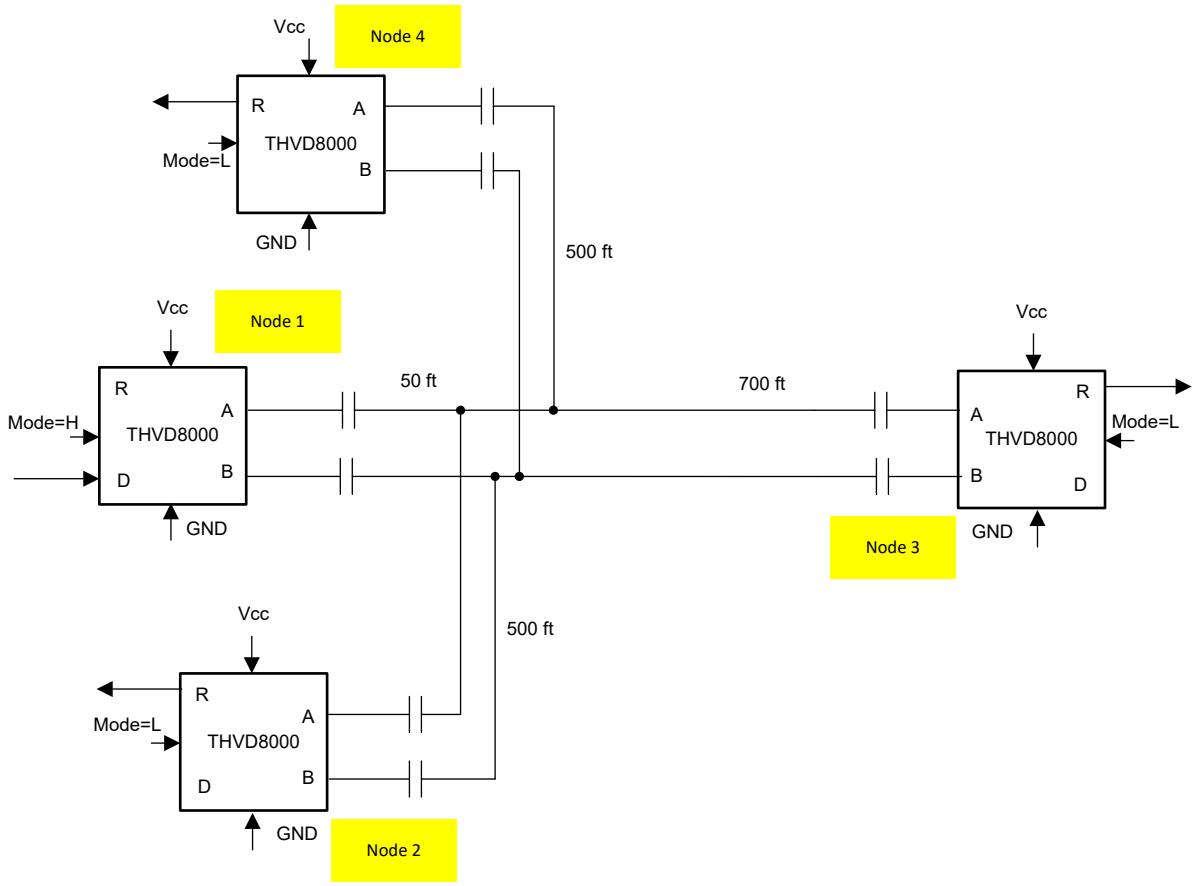

Figure 2-1. 4-Node Star Network

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Communication data is generated by a third-party software (Serial Port Utility), which follows the UART protocol with a baud rate of 115200. As shown in Figure 2-2, a string **1122334455667788990AABBCCDDEEFF** in hexadecimal (hex) format has been chosen to be transmitted as shown. The same software in a separate graphical user interface (GUI) can be used to check received data. If the computer does not have enough serial communication ports (COM) to check signal at 4 nodes simultaneously, a 1 to 4 USB hub and 4 TTL-232R cables from Future Technology Devices International Ltd. can be used. Therefore, one physical port is occupied, while 4 virtual ports are created by the operating system.

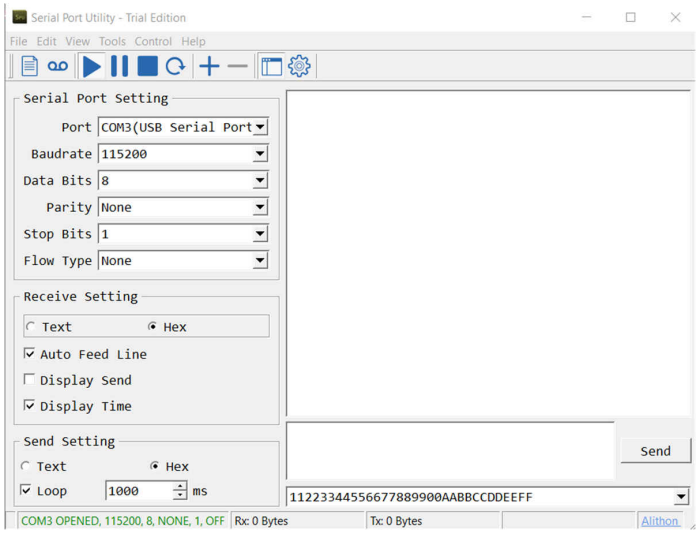

Figure 2-2. Serial Communication Software GUI

One node is set as the transmitter by setting the mode pin (pin 2) high (Node 1 in Figure 2-1), while the other three are set as receiver. In this bench test, waveforms are captured at Node 1 and Node 3. In the snapshot of Figure 2-3, channel 1 is the transmitting signal of the D pin (pin 4) of Node 1, while channel 4 is the differential bus signal near the bus pins (pin 6 and pin 7) of Node 3. The bus signal has several toggling waveforms with small amplitude after the 0-to-1 transition, which is due to the reflection generated by long stubs and open ends. Channel 2 is the receiver output (pin 1) of Node 3. Because of the disturbed bus signal, the receiver generates 0 when it is supposed to stay as 1. This kind of signal integrity issue can be problematic in applications due to high error bit rate in communication.

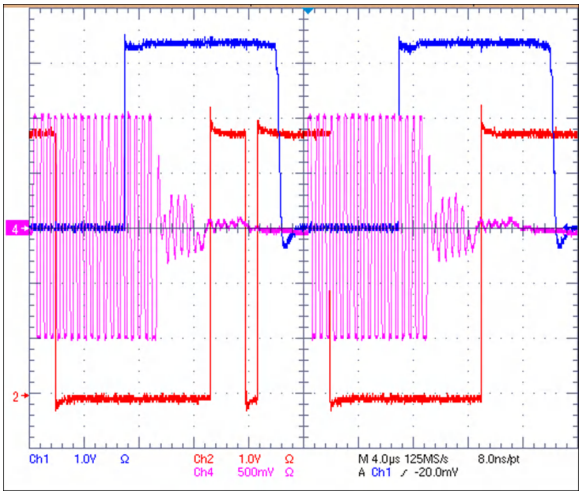

Figure 2-3. Waveforms of 4-node star network

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2.2 Test 2: 4-Node Terminated Star Network Test

To make THVD8000 work for the 4-node star topology, the system is improved by terminating every node with a 120-Ω resistor like Figure 2-4.

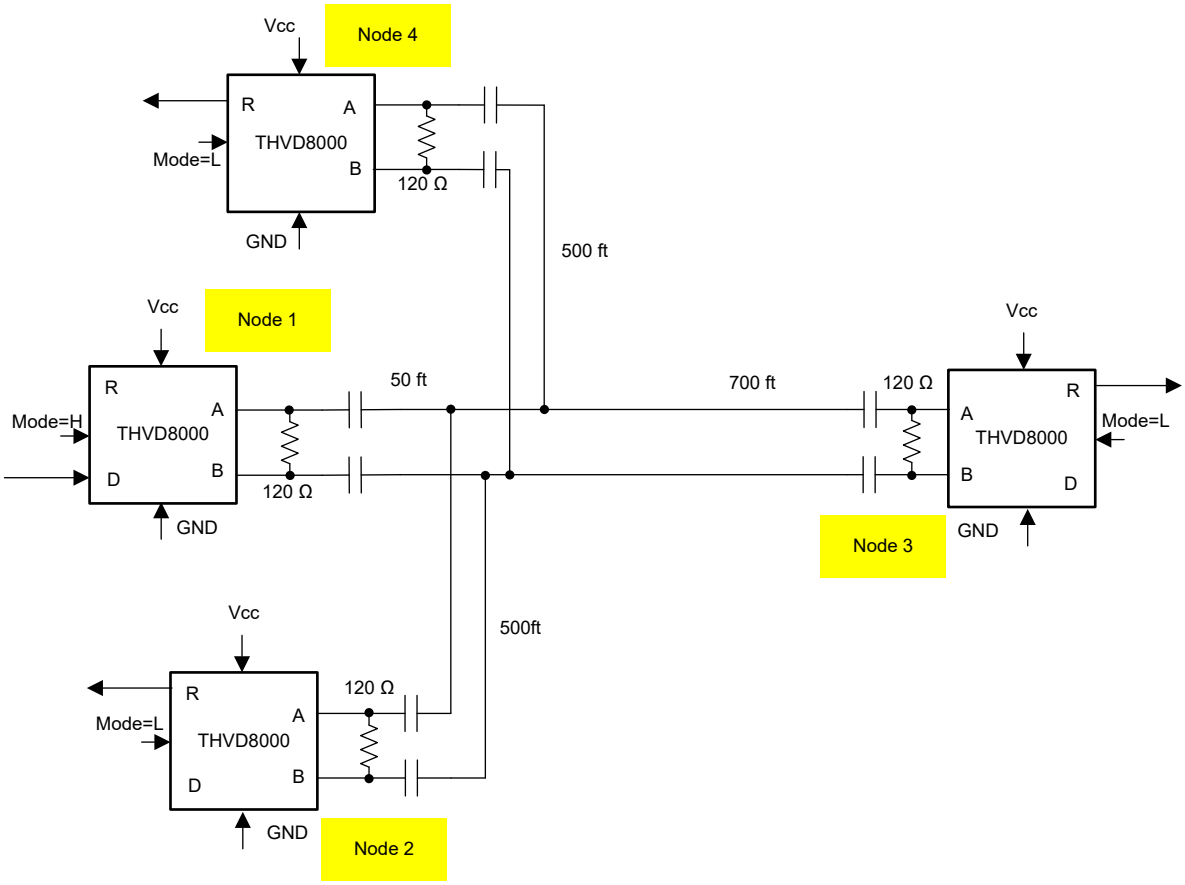

Figure 2-4. 4-Node Terminated Star Network

The termination resistance matches the cable's characteristic impedance. Therefore, signal reflection is minimized and signal integrity is improved greatly, which is shown in the waveforms of Figure 2-5. The signal is measured at the same locations as in the last test – D of Node 1, bus pins and R of Node 3.

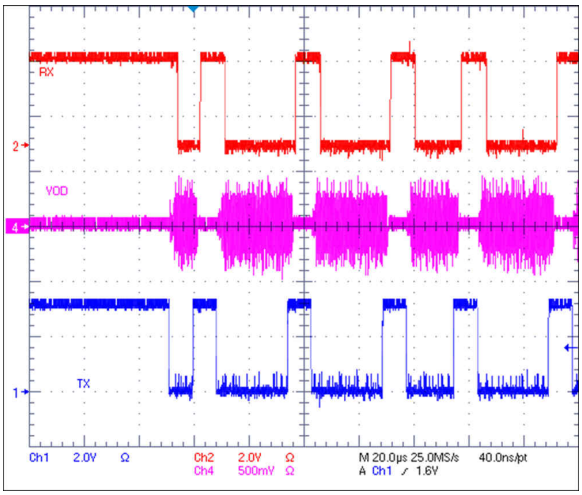

Figure 2-5. Waveforms of 4-Node Terminated Star Network

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With the 1-to-4 USB hub and TTL-232R cables mentioned previously installed, all data are checked in 4 GUI windows. In Figure 2-6, COM3 is Node 1 that transmits the data, while COM4, 5 and 6 are in the receive mode of Node 2, 3, and 4. With sending and receiving the string repeatedly, the communication is proven to be successful in this configuration. Then each node in the network is set to send data, while the rest nodes are checked for receiving data. By doing this, the quality of communication is verified for all the nodes.

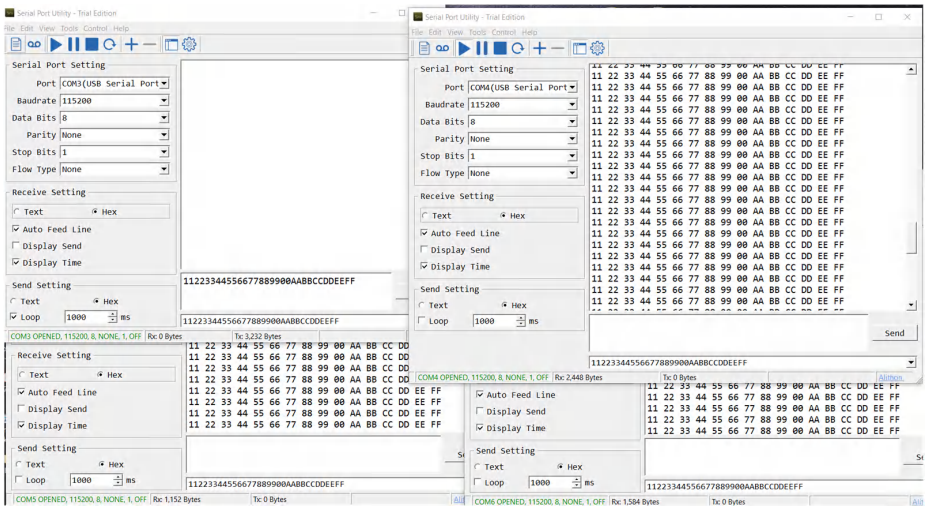

Figure 2-6. GUI of 4-COM Ports of the 4-Node Terminated Star Network

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2.3 Test 3: 4-Node Loaded and Terminated Star Network Test

Although adding termination at each node works for the 4-node network, it is logical to wonder if it performs well with a system with many more nodes. To mimic the load of multiple nodes, a 3-Ω resistor represents the lumped load of 40 terminated nodes (Figure 2-7). The lumped load is placed near the transmitter to minimize the impact of long cable.

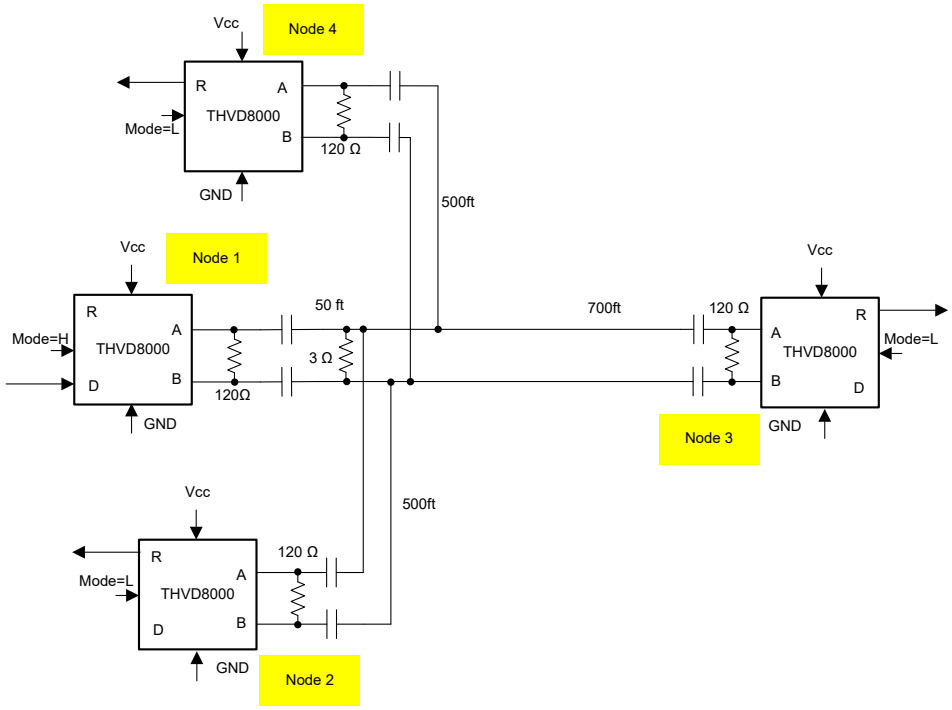

Figure 2-7. 4-Node Loaded and Terminated Star Network

From the GUI and signal integrity check, the communication still works. To conserve space, the GUI looks the same as Figure 2-6 and is omitted for this test. However, it is noticeable that the amplitude of the received signal is significantly reduced (Figure 2-8) due to heavy load and is near the threshold of the THVD8000's receiver. The small signal has poor signal-to-noise ratio that could create problems in noisy real-world environment.

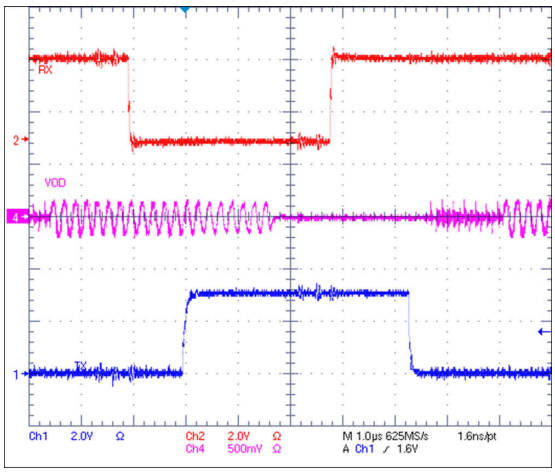

Figure 2-8. Waveforms of the 4-Node Loaded and Terminated Star Network

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2.4 Test 4: 4-Node Loaded and Terminated Star Network Test with Line Driver

Next step of system improvement is to support such multiple-node system with a low-impedance load. To increase the signal's noise margin, a high-speed amplifier is added after the THVD8000 to drive the bus as shown in Figure 2-9. Here a differential amplifier, THS6222, is chosen and powered by a 12-V supply. Based on the data sheet, this amplifier output impedance is 0.01-Ω at 1-MHz and the device has 195MHz large swing bandwidth. To prove the idea, only one THS6222 is added at Node 1, while the THVD8000 directly receives the signal in the other three receiving nodes. In proper system design, THS6222 is inserted into the signal path in the drive mode and bypassed in the receive mode.

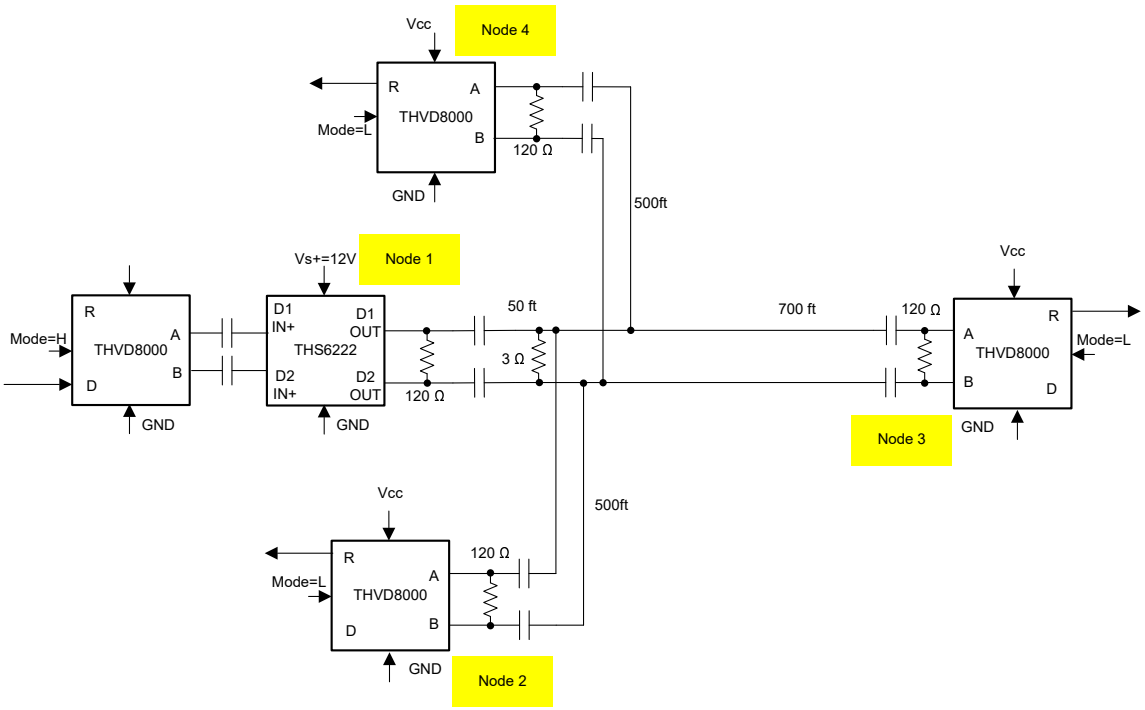

Figure 2-9. 4-Node Loaded and Terminated Star Network with Line Driver

With the help of the THS6222, the drive capability is increased significantly. Comparing Figure 2-10 to Figure 2-8, the amplitude of bus signal is increased more than two times. Similarly, the GUI reports are skipped here. Since THVD8000's pin has the +/-15 V abs max, the receiver has no problem working with large swing signal generated by the high-speed amplifier. Again, this setup represents a 40-node star network system, meaning the implementation has the potential to work with various other topologies.

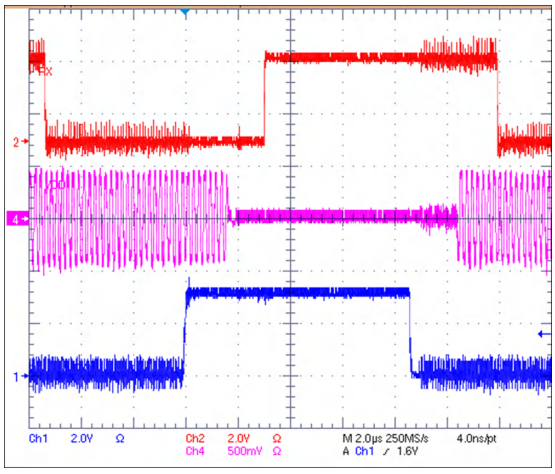

Figure 2-10. Waveforms of the 4-Node Loaded and Terminated Star Network with Line Driver

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3 Summary

In summary, several tests are presented for the star network systems. Specifically, two techniques are discussed in detail. First, terminating every stub of non-daisy chain network can greatly improve signal integrity, which will widely expand the use cases of RS-485 systems. Second, high speed amplifiers can be used as line drivers for PLC applications to drive low-impedance systems. Other than the heavy load system discussed here, outlet AC power line usually has low impedance, where this technology can be applied too. The measurement data presented in this application note hopefully will give the designers more ideas about special RS-485 and PLC systems.

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