Application Note

Simplifying Surge Protection for RS-485 Using Integrated Designs

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ABSTRACT

When dealing with surge transients within RS-485 systems most designers have to work with some type of protection circuitry, whether it be discrete (most common) or integrated within the transceiver itself. This protection circuitry is paramount to adding a layer of robustness to the system design to survive harsh operating conditions and/or high voltage transients. Not only does the protection need to be able shunt a large amount of current towards the system ground, but also maintain a voltage level within the absolute maximum and minimum ratings of the transceiver. RS-485 devices integrated with surge protection like the new THVD2419 and THVD2429 from TI's new high stand off voltage surge protected THVD24x9x family or the classic surge protected THVD14x9 family offers multiple simpler solutions for implementing surge protected RS-485.

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Trademarks

1 Introduction

RS-485 is a long-standing wired interface standard that allows for relatively high speed, robust, and long-distance communications. Many RS-485 systems can be subject to high voltage surges due to events such as lightning strikes on the system and the systems must be able to survive during one of these events. Most classical RS-485 transceivers are not able to handle these high voltage transients on the bus facing pins without sustaining damage – so more complicated protection schemes are used in the design to increase the robustness in the face of high voltage transients. At the core of all these protection schemes is a device that can clamp the bus voltage, a protection diode. In the past designers mostly looked to fully discrete designs that range from clamping diodes and current limiting resistors to more complex configurations that can include TBUs (transient blocking units) and MOVs (metal oxide varistors) as well.

As RS-485 transceivers have evolved, additional protection features such as integrated surge diodes have been implemented in some special use RS-485 devices, as can be seen in the THVD2419, THVD2429, as well as the THVD14x9 family of devices. However, as diodes start to shunt current the voltage on the line can increase, the clamping voltage of the line is directly related to the current shunted through the diode. With many RS-485 devices having asymmetric min and max voltage ratings that are under +/-15V finding the correct diode and current limiting resistor that not only protect the device during surges, but allow for high quality communication during normal operation can be the bane of designers working on a relatively simple protection scheme.

This limitation can be worked around with TI's new line of integrated surge devices in the THVD24x9x family including devices like THVD2419 and the THVD2429. These devices not only boast an integrated surge diode for protection, but also offer high fault protection on the bus facing pins – with the pins being tolerant of up to ±42V with respect to the circuit ground

To fully understand the benefits of this new line of devices three main points can be covered. First, an understanding of discrete surge designs for RS-485 and what design challenges designers face. Second, how the integrated surge simplifies the system design. Finally, why the higher stand-off voltage separates a design using the THVD24x9x from other surge protected RS-485 designs.

2 Discrete Approach to RS-485 Surge Protection

Most classical RS-485 devices, while robust in the face of many standard industrial environments, still cannot withstand a high voltage surge on the differential communication bus pins without sustaining damage. Many industrial system designers when faced with this problem can employ a discrete protection network, which depending on the on the characteristics of the surge signal the transceiver can be exposed to can vary in complexity. However, before a discussion of common discrete protection circuits are discussed, a way to evaluate the surge signal can be discussed.

Many designers, when contemplating surge protection, need a way to quickly quantify the amount of surge protection received. A common standard, and the one that TI also evaluates to, is IEC 61000 4-5 which is a common standard that devices such as TVS diodes, gas discharge tubes (GDT), and Metal Oxide Varistors (MOV) use to standardize a parameter for surge immunity. It is typical to test with a 1.2/50 – 8/20us surge generator – where the voltage waveform has a 1.2us rise time and 50us fall time with the current waveform having an 8us rise time followed by a 20us fall time. This standard is what underpins what surge immunity means to many devices, including those from TI. Both a 0.5kV and a 6kV surge showing the power over time are shown in Figure 2-1

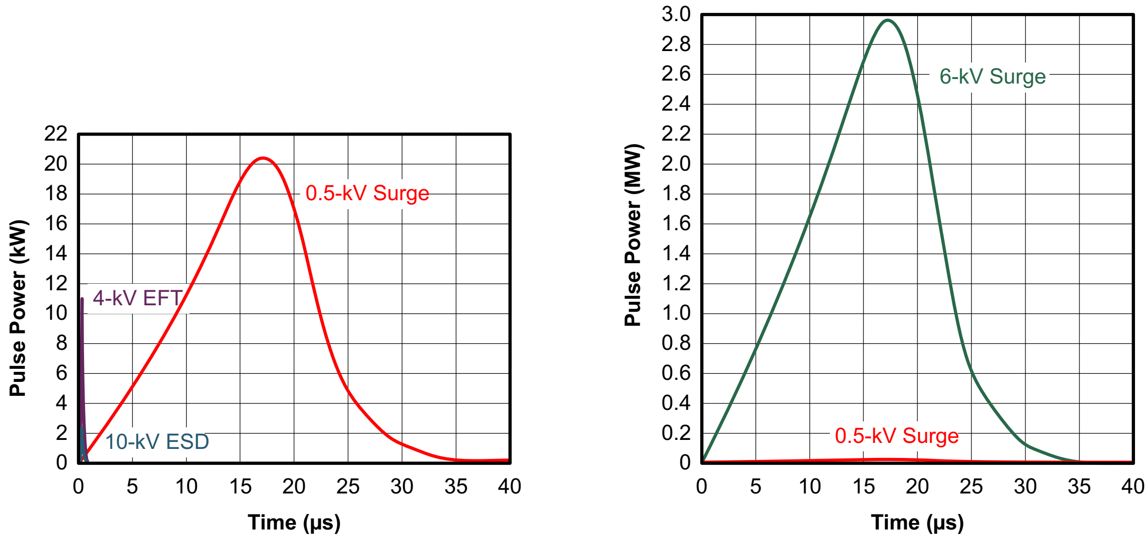

Figure 2-1. Surge and ESD Power Comparison

The simplest protection scheme works by limiting current, clamping the line voltage, and additional filtering of the peak surge current coming into the differential line.

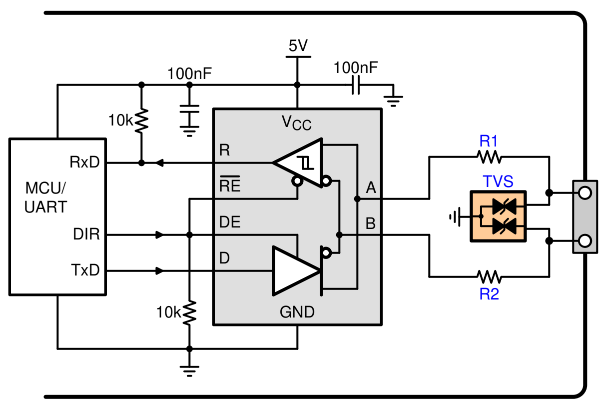

Figure 2-2. RS-485 Half Duplex Transceiver with Basic Discrete Surge Protection

In Figure 2-2 the incoming surge at the port has the current limited to set the clamping voltage of the TVS diode. It is very important to understand what level the diode can clamp the bus to under expected surge conditions – the current shunted through the diode can be directly related to the bus clamping voltage so it is very important to have current limiting between surge source and bus protection. R1 and R2 are low value resistors that are pulse proof – typically the resistors can be thick film or wire wound and sized to about 10Ω. These resistors help filter off the short-lasting peak voltages coming in from the bus which further increases the overall rating of the node. Many TI RS-485 data sheets suggest using the CDSOT23-SM712 diode paired with CRCW0603010RJNEAHP thick film resistors.

Table 2-1. RS-485 Half Duplex Transceiver with Basic Discrete Surge Protection BOM

Component	Package Dimensions	Package/Design Area
CDSOT23-SM712	2.9mm x 2.3mm	6.67mm^2
CRCWO603010RJNEAHP	1.55mm x 0.85mm	1.3175mm^2
Standard 8-Pin RS-485 Transceiver in SOIC package	4.9mm x 3.91mm	19.16mm^2
Total Design Size: (2 Resistors, 1 IC, 1 diode)	N/A	28.465mm^2

Adding the two resistors and diode necessary for basic surge protection adds almost 50% of the IC package space to the total space budget. This also does not include layout considerations that can also end up increasing the total design size. The aforementioned design is something TI only recommends to about ±1kV surges, but higher surge levels can require larger diodes.

It is important to understand the maximum voltages that can be seen by the transceiver. If the bus clamps too high, the transceiver can still be damaged, so it is critical for the designer to keep track of the clamping voltage of the bus. Beyond size increases and strict voltage maximums of the transceiver this design has one other flaw – the surge voltages must be relatively short lasting. The TVS diodes typically used in RS-485 protection systems cannot sustain high amounts of current being shunted through them indefinitely. Also, if the diodes are left too long under high current conditions the diodes can break and the resulting spike in voltage on the bus can result in a damaged transceiver as well as destroyed protection devices.

While the simple approach to protection as previously discussed has a lot of benefit to many systems, other systems can require more robust approaches. A tried and true method of achieving even higher levels of protection in the system is to employ Transient Blocking Units (TBUs) and Metal Oxide Varistors (MOV) in addition to the simple network described previously.

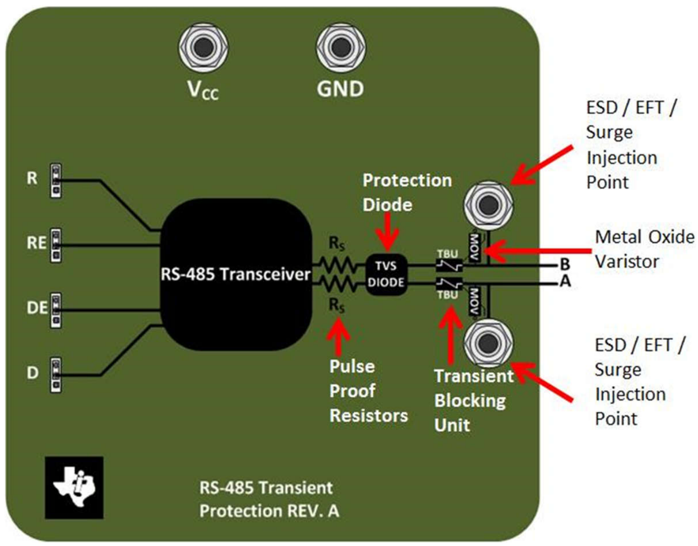

Figure 2-3. Robust Discrete Surge Protection for RS-485 Bus

Figure 2-3 shows that the simple network of TVS diodes and pulse proof resistors still exists in the same position as it can be in a simpler protection scheme. However, the TBUs and MOVs have also been added to increase the robustness. The TBUs are shown as both a current limiter as well as a voltage disconnect circuit. During an overvoltage or overcurrent event, the TBU can limit the current running through the device then after a brief delay can effectively break the load off, including the RS-485 device, from the surge source. The MOVs act similarly to bi-directional surge diodes and additional clamping stage to the bus for protection under large surges. They do not protect against in-rush current and can possible have issues with sustained current faults. Due to these limitations, they are paired with the TBU to help add current protection as well as voltage clamping on the main bus line.

In most surge protected RS-485 systems, either the simple or complex variation can be found, while there can be outliers – these two designs are considered well tested for specific protection needs. However, with each additional element added to the board, the complexity of the design and board space needed increases which can put considerable strain on the designer to adequately meet all of the design goals.

3 Integrated Surge Protection and the THVD14x9 Family of Devices

With a basic understanding of how surge protection works on the RS-485 bus, the next question a designer needs to be asking *is there a better option to help simplify the design while also maintaining a well-protected system?* Fortunately, there is a design to this question – integrated surge protection in an RS-485 device. Considering that at the heart of any surge protected RS-485 communication node there is a TVS diode that helps clamp the bus voltage during transient overvoltage events a logical next step is to integrate the TVS diode internal to the RS-485 device. TI and the THVD14x9 family of devices was created to fill this need by integrating the simple protection design into the transceiver package.

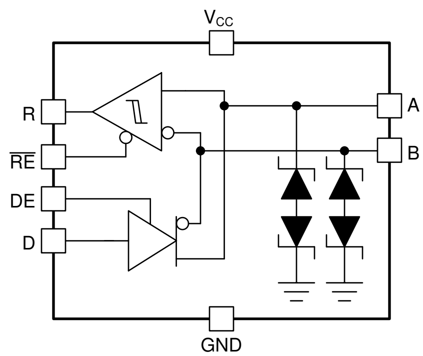

Figure 3-1. THVD14X9 Family of Devices Functional Block Diagram

There are two major benefits from replacing the discrete protection scheme in favor of the integrated design. The first is ease of design - considering non-surge protected RS-485 devices do not have any specific surge rating attached to them the protection network must be rated for the incoming surges as well as respect the voltage ratings on the transceiver which presents the design challenge of converting surge waveforms into peak voltages seen by the transceiver. However, an integrated design such as a device in the THVD14x9 family from TI helps solves this problem by testing in accordance with IEC 61000 4-5 which standardizes the surge generator as well as the characteristics of the surge waveform.

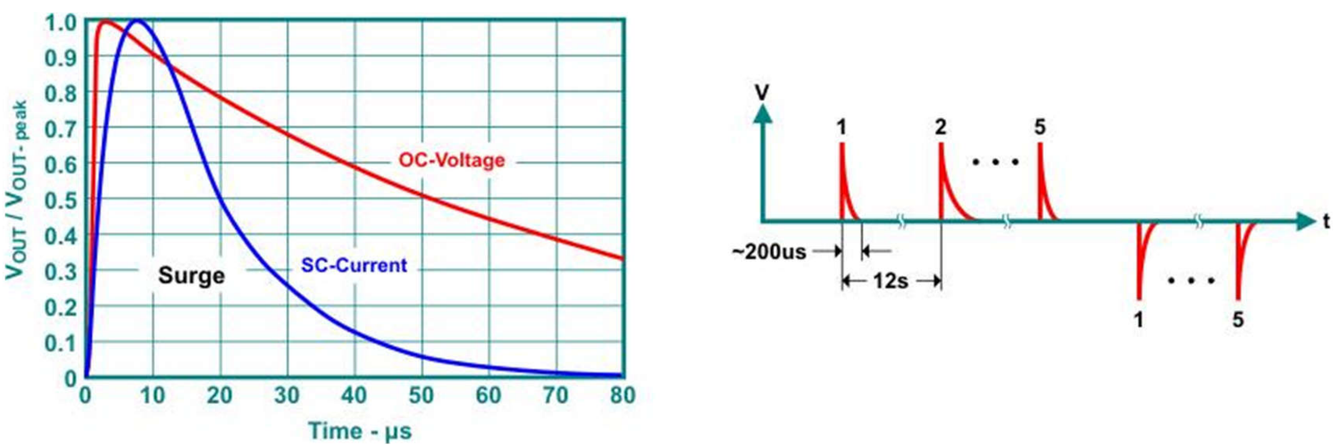

Figure 3-2. Surge Test Characteristic

Figure 3-2 shows the normalized waveforms for both Open Circuit Voltage and Short Circuit Current. Figure 3-2 also shows the repetition rate in a standard surge test. This standard is a very common way to evaluate surge protection across multiple types of protection devices. In the traditional discrete implementation the transceiver has no rated surge protection – yielding another unknown that the designer must determine, but with an integrated surge device with an IEC 61000 4-5 rating the designer can immediately know what level of surge the device is rated for. An example of this is the THVD1419 which has an IEC 61000 4-5 rating of ±2.5kV. However, if looking at the discrete implementation the protection rating on the diode does not necessarily translate 1:1 to the protection rating of the node if the diode clamps too high at the rated surge voltage. Using an integrated surge device alleviates this risk by giving the transceiver a protection rating.

The next major benefit of using an integrated surge design is size reduction. Due to process and technological improvements over time the RS-485 transceiver as well as protection diodes can fit an in industry standard 8-pin SOIC device - which takes up approximately 19.16 mm^2 of board space. If using a common RS-485 diode for a discrete design with the standard SOIC package there can be an increase of about 50% for the design size. This is avoided when using the integrated design. Even if more robust protection is needed, such as TBUs and MOVs, the integration of the TVS diode can still reduce overall design size even in systems that require additional external protection.

While the two major benefits of using an integrated surge, device are clear – there is one downside. The downside is that there is a lack of flexibility when using the integrated design. While using the integrated design can trim down the unknowns for the design to determine, it also limits the options the design has when implementing a system. The THVD14x9 family is still largely bound by standard RS-485 limitations – meaning a more standard common mode range – which for the THVD14x9 family is ±12V. This is generally acceptable in many systems, but for systems with large ground currents or large distances between nodes the ±12V common mode range may not be enough for proper communication to occur in these systems. Another example to highlight this issue is the protection rating – if a higher protection rating than offered is needed there is most likely a discrete implementation that can meet the design goal which renders paying a premium for an integrated design not the best path forward. While this still shows that the integrated surge protection on standard RS-485 devices is very beneficial for more typical applications it does fully cover the application space of protected RS-485. However, one of these issues has been solved from TI's latest surge protected RS-485 offerings – the THVD24x9x family of devices.

4 THVD24x9x – The Next Generation of Integrated Surge Protected RS-485 Devices from TI

Until recently the trade-offs between integrated and discrete protection was straight forward. Discrete designs offer more flexibility in the design at the cost of a higher design complexity, while integrated designs offered a simpler and smaller design with at the cost of a narrower design scope and the premium paid for the integration. To combat the issue of the narrower scope on the previous generation of surge protected RS-485 Transceivers, TI's new THVD24x9x family increases the flexibility of applications that can be supported by raising both the stand-off voltage range as well as the common mode voltage range.

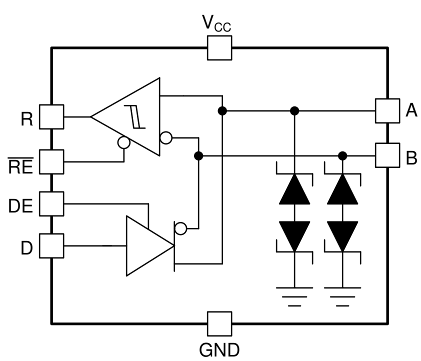

Figure 4-1. THVD24X9 Family of Devices Functional Block Diagram

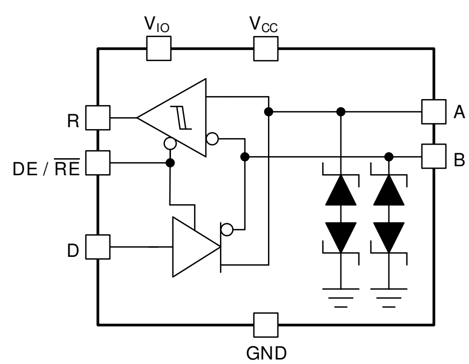

Figure 4-2. THVD24X9V Family of Devices Functional Block Diagram in SOIC Package

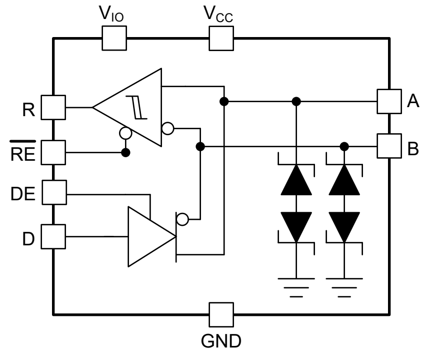

Figure 4-3. THVD24X9V Family of Devices Functional Block Diagram in VSON Package

The next generation in surge protected RS-485 from TI offers multiple benefits above the last generation of integrated surge. These can be broken down into three main categories: standard RS-485 operation, design size, and controller interface.

When looking at standard RS-485 operation the THVD24x9x family, including devices like THVD2419 and THVD2429, offers extended common mode voltage ratings of up to ±25V as well as stand-off voltages of up to +/-42V in addition to their IEC 61000 4-5 ratings (±2.5kV for SOIC packages and ±1.5kV for VSON packages). This allows an integrated surge protected device in systems where large ground potential differences are likely – this is especially important in systems where the transceiver is connected to a motor as during operation systems with a motor can put a large amount of current on the ground line. In systems with large ground lines this can create large voltage drops on the reference plane between nodes. Standard RS-485 expects this to some degree – but in some industrial systems the standard level isn't enough. In the past this can mean picking a different transceiver that supports higher common mode and placing a discrete protection design in front – but the THVD24x9x family of devices prevents this requirement by allowing a large common voltage range during normal operation.

Another benefit of the THVD24x9x family of device is that beyond the standard 8-pin SOIC package it also has offerings in the smaller 10-pin VSON package which only takes up 9mm^2 of area. Not only does the designer get the size reduction in a standard SOIC package, but they can use the VSON package and only use 9mm^2 of board space for the simplest form of surge protection. Using the discrete example from section one, the diode plus pulse proof resistors takes up more space, 9.3mm^2 than one of the VSON offerings from the THVD24x9x family of devices. This means a classic discrete implementation has the protection circuit bigger than the THVD24x9x in a VSON package which not only gives the integrated protection, but also gives the transceiver as well in a tiny 3mm x 3mm package.

Finally, another major benefit is the devices in the THVD24x9x that take the form THVD24x9V have an additional supply pin that can allow a separate voltage supply for the RS-485 bus as well as a separate supply for the logic pins. This separate supply pin can be powered as low as 1.65V allowing a 1.8V controller to control the RS-485 node. Without the separate supply pin an additional level translation circuit can be introduced. Not only does the THVD24x9V line of devices integrate protection, but also integrates level translation allowing for a much more flexible use RS-485 device that also protects in the case of surge transients.

5 Summary

Surge protection is a necessary part of many RS-485 designs. In the past, designers were primarily forced to use discrete protection implementations – which varied from simple diode and resistor setups to more robust architectures including MOVs and TBUs. TI's two main lines of surge protected RS-485 devices, THVD14x9 and THVD24x9x, can help designers simplify their surge protected RS-485 systems. Using one of TI's surge protected offerings can help a designer, simplify design and component selection, reduce the total design size of the system, be placed in either more standard RS-485 systems (using the THVD14x9 line with devices like THVD1419 or THVD1439) or harsher RS-485 systems which can require larger standard operational ranges (using the THVD24x9x line with devices like THVD2419 and THVD2429).

6 References

- Texas Instruments,*Design Guide: TIDA-00731 IEC ESD, EFT, and Surge RS-485 Bus Protection Design Guide* reference design.
- Texas Instruments, *THVD14x9 3.3-V to 5-V RS-485 Transceivers With Surge Protection* data sheet.
- Texas Instruments, *THVD14x9x 3-V to 5.5-V RS-485 Transceivers With 4-kV Surge Protection and 1.8-V VIO Capability* data sheet.
- Texas Instruments, *THVD24x9 3V to 5.5V RS-485 Transceivers With Integrated Surge and High Bus-Fault Protection in Small Packages* data sheet.