Application Note

Protecting Ethernet Ports from Surge Events

ABSTRACT

Ethernet networks are subject to many harsh conditions as a function of being in industrial applications. One particularly harsh condition is a transient surge highlighted in IEC 61000-4-5. This surge pulse is applied on the transmit and receive lines of the ethernet physical layer and can potentially damage the ethernet controller, or phy. One statement that inevitably comes up during this discussion is that the transformer in the system should isolate the sensitive phy from the pulse on the connector. However, as shown in this application report, transient pulses can couple through the transformer and potentially damage the ethernet phy. This means that adding protection between the transformer and the phy is necessary in harsh industrial environments that will be subject to transient surges.

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1 Introduction

Ethernet has been widely adopted in industrial markets as a robust way to transmit signals. In these industrial markets the physical layer of the Ethernet system is subject to harsh environment that can stress the system as a whole. Surge transients are particularly dangerous for these system as they represent a large amount of power that is coupled onto the transmit and receive circuitry of the Ethernet physical layer. This document goes through the dangers of surge pulses in Ethernet applications showing why and what protection is needed to make sure the Ethernet controller can survive these transients.

2 Ethernet Protocol

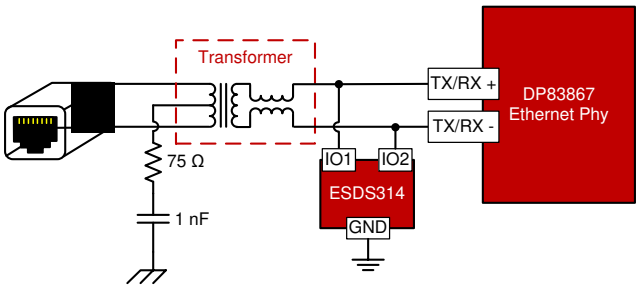

Figure 2-1. Ethernet Physical Layer

2.1 Physical Layer

The Ethernet physical layer involves the Ethernet phy (or controller), a transformer and a RJ-45 connector as can be seen in Figure 2-1. Additionally there are shunt capacitors placed on the phy side while there is an RC filter placed on the center tap of the transformer towards the connector side. When placing an surge protection diode in the schematic, there is the option to place it before or after the transformer. On the connector side of the transformer, the common mode voltage is uncontrolled. In the typical application the voltages will be low but in power over Ethernet (PoE) or a high voltage line coupling onto wires extending from the connector can mean that the line is subject to very high common mode voltages. Therefore the selection of surge protection diodes is extremely limited to ones that have a high enough breakdown voltage to not turn on during the high common mode voltages but absorb the transients. Additionally, having surge protection devices mean that they have to take the entirety of the surge pulse. This is extremely problematic as surge events can go up to 6 kV with currents reaching 100 A. Extremely few surge diodes are capable of handling that much energy and would have so much capacitance that it would be impossible to have a high speed signal sent through.

2.2 Isolating Transformer

Having the transformer in the system means that there is isolation between Ethernet wires such as CAT-5 or CAT-6 and the Ethernet controller or phy. Transformers however do have parasitic elements associated with them. Figure 2-2 shows the different parasitic elements present in a transformer specifically highlighting one that is the culprit for why there is not full isolation in a transformer. On both the primary and secondary side of the transformer there is a parasitic capacitance, resistance and inductance that is present in all real world small signal analysis. These are due to the nature of the material and their proximity to each other. However with having both the primary and secondary wound next to each other, there is a winding capacitance introduced.

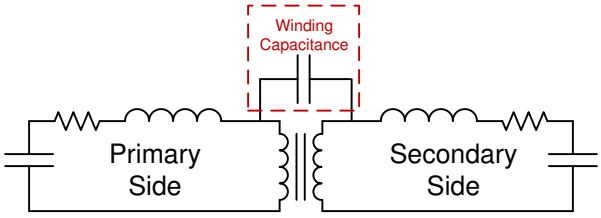

Figure 2-2. Transformer Schematic with Parasitics

$$I = C * dV/dt \quad (1)$$

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Equation 1 is the equation for a current through a capacitor. Since the surge pulse is providing a large dV/dt on the primary side, the capacitor will have current flow from the primary side to the secondary side but not fully isolating the two sides. This pulse seen on the secondary side is a percentage of the primary side which at high levels can easily damage IC connected. Therefore this pulse must be measured and protected against.

3 Surge Pulse On Transformer

Therefore the question that comes up is how necessary it is to have surge protection on the side of the transformer that is not exposed to the harsh environment? There are two types of surge pulses that can happen to the lines: differential and common mode surge. The common mode surge happens when a high energy pulse capacitively couples onto all of the lines equally raising the common mode voltage. This can happen during lightning strikes or other events but interestingly enough, the transformer can easily dissipate this energy to the earth ground. This also means that the RC filter put on the center tap of the transformer plays a role in protection. Looking at the isolated side of the transformer, it can be seen that not much of the pulse gets through which means that the phy is protected until the transformer itself fails.

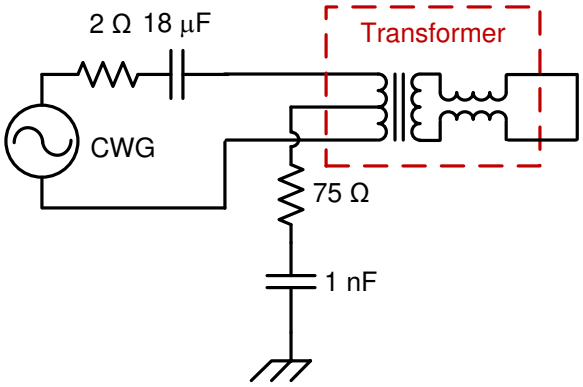

Figure 3-1. Differential Surge

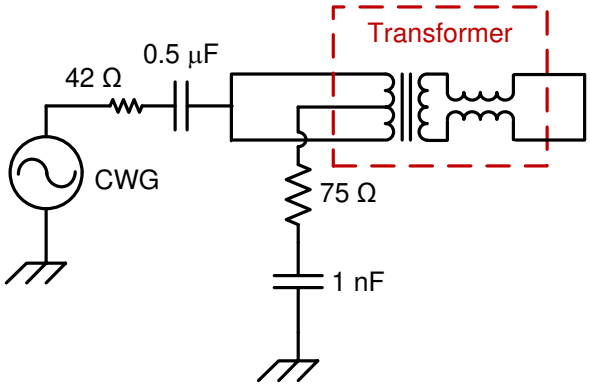

Figure 3-2. Common Mode Surge

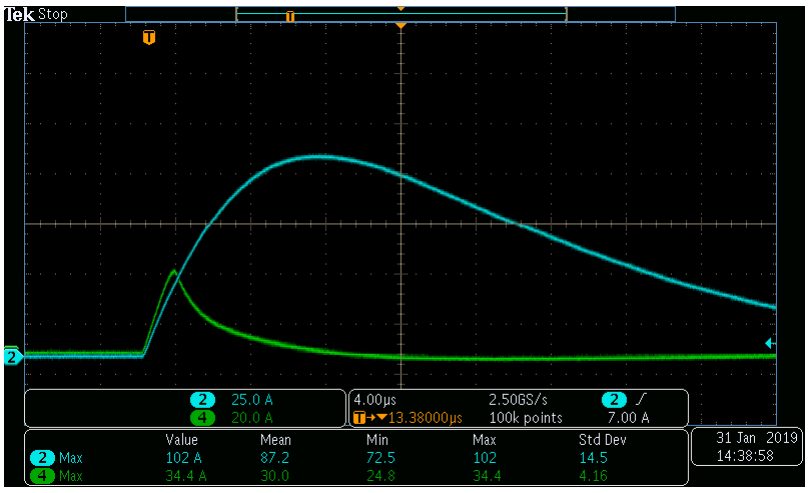

Figure 3-3. Differential Surge Waveform on Transformer

However, differential surge is quite different. Differential surge is when the surge pulse is coupled directly on the signal line and returns on the other signal line. This type of surge pulse is very dangerous for Ethernet controllers because a portion of the surge pulse actually goes through the parasitic capacitance of the transformer and causes a current spike. This pulse can be seen in Figure 3-3. It is important to note that the reason there is no voltage on the secondary side of the transformer is because it is shorted together.

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3.1 Surge Protection Diode on Secondary Side of Transformer

Therefore since it can be seen that although the pulse that is transferred through the transformer is reduced in peak and width, it could still potentially damage the phy. Using the same surge set up and adding in the ethernet phy, the picture below shows the point just before and after it breaks the device. Notice that the voltage that is measured on the secondary side is relatively high. This is due to the high clamping voltage of the internal ESD protection of the phy. The waveforms below were taken measuring the current on the primary side in blue, the current on the secondary side in green and the voltage on the secondary side in yellow.

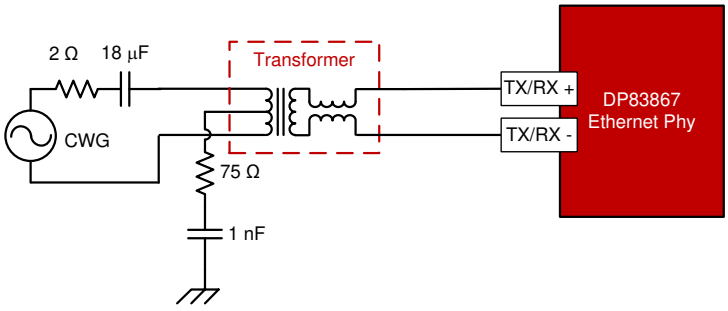

Figure 3-4. Surge Pulse Setup with Transformer and Ethernet Phy

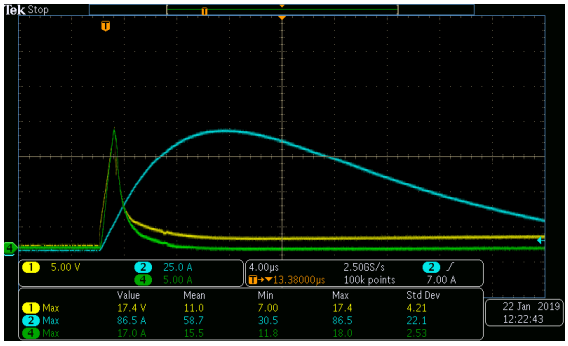

Figure 3-5. Diff Surge Pulse Just Before Phy Breaks

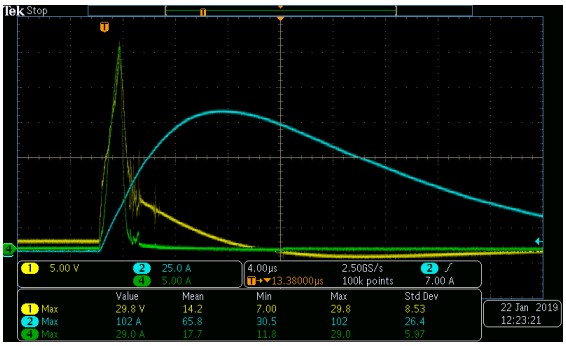

Figure 3-6. Diff Surge Pulse After Phy Breaks

Rerunning the same test but adding in the ESDS314 onto the signal lines that the surge was applied to, it can be seen that the device is protected from this event.

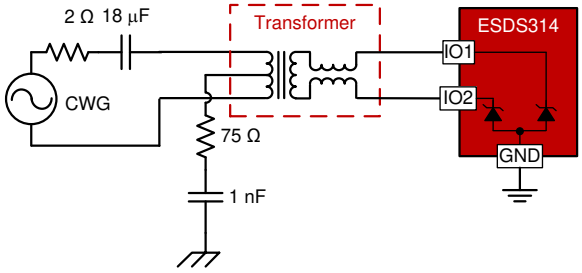

Figure 3-7. Surge Setup with Ethernet Physical Layer and ESDS314

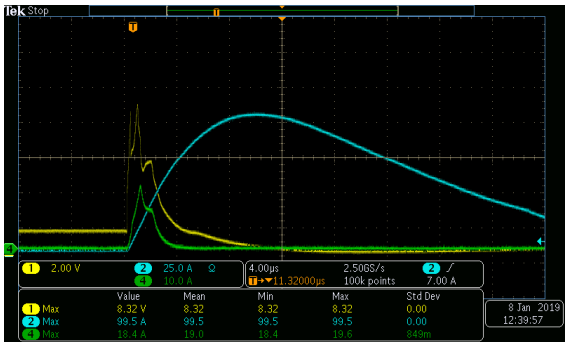

Figure 3-8. Differential Surge Waveform with ESDS314 and Phy

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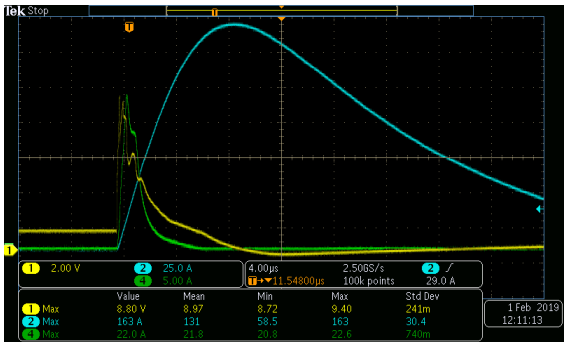

Figure 3-9. ESDS314 Protecting Phy From Differential Surge Pulse at 160 A

4 Conclusion

Ethernet is widely used in a bevy of industrial end equipments. The Ethernet protocol consists of a transformer that is suppose to isolate the outside world and the Ethernet controller. However due to the parasitic nature of real transformers, there is not true isolation between the primary side and secondary side. This causes issues when the Ethernet physical layer is exposed to a surge event as the pulse couples through the parasitic capacitance and can damage the controller on the secondary side. Therefore it is necessary to provide protection on the secondary side of the transformer that can handle the large currents produced. TI's ESDS3XX devices have high surge current rating that allow them to dissipate this energy and protect the Ethernet controller.

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5 Revision History

Changes from Revision * (February 2019) to Revision A (April 2022)	Page
• Updated images for *Diff Surge Pulse After Phy Breaks* and *ESDS314 Protecting Phy from Differential Serge Pulse at 160 A*	4

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