Increasing System ESD Tolerance for Line Drivers and Receivers Used in RS-232 Interfaces

National Semiconductor
Application Note 878
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January 1993

OVERVIEW

The Data Transmission Applications Group at National Semiconductor investigated field failures of TIA/EIA-232-E (RS-232) DS14C88 Line Drivers and DS14C89A Receivers. The devices are commonly used in computer Input/Output Interfaces, such as a terminal-DTE (Data Terminal Equipment) to modem-DCE (Data Circuit-terminating Equipment) interface. Upon completion of detailed failure analysis on the devices, it was determined that they failed due to electrical over-stress, more commonly known as EOS.

In order to identify the source and type of EOS, a number of DS14C88 and DS14C89A devices were subjected to controlled Electrostatic Discharge — ESD (Electrostatic Discharge) events in the lab using a KeyTek Human Body ESD Simulator, (per IEC801-2 requirements). Additional units were tested with PolyClamp® ESD protection devices to determine their effectiveness and to demonstrate a possible solution for providing greater system ESD tolerance.

The following conclusions have been made as a result of the investigation and bench testing:

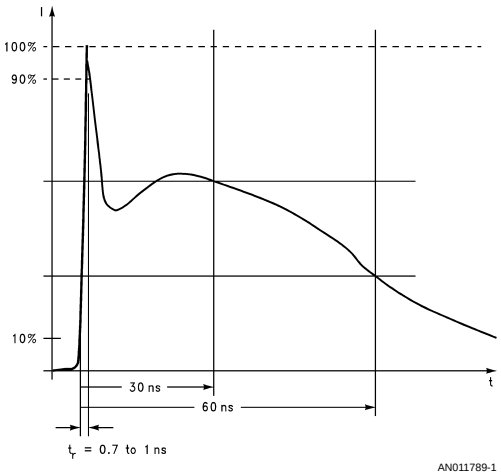
- The pins most commonly damaged are Driver Output and Receiver Input. This implies that the EOS is reaching the IC from the “outside world” via the interface cable and connector. Damage was not seen on driver input or receiver output pins.
- The external source was determined to be an ESD event by matching the failure modes and comparing die photographs of the lab induced failures with the field failures.
- The DS14C88 Line Driver and the DS14C89A Receiver would incur functional failures when subjected to an ESD event below 5,000V without the use of any external ESD protection devices.
- With PolyClamp ESD protection devices installed in the test fixture, all the IC’s passed parametric and functional tests at the maximum tested ESD level of 15,000V per IEC 801-2 Specification.

INTRODUCTION

The DS14C88 Quad Line Drivers and the DS14C89A Quad Receivers are predominantly used on TIA/EIA-232-E (RS-232) serial interfaces that connect DTE’s to DCE’s or other DTE’s. The driver outputs and receiver inputs are connected to the outside world through: a printed circuit board (PCB) trace, a connector, and a cable. The driver outputs and receiver inputs are exposed to the outside world (i.e., off the PCB). These devices can be damaged by ESD events that can be directly discharged to the connector pin. To prevent damage to the parts external transient voltage suppression (TVS) diodes have been used in the past to clamp transients to levels that the driver outputs and receiver inputs can withstand. This approach requires a board modification, and a substantial amount of PCB real estate, not to mention cost. This application brief describes a new technology that is available to provide greater ESD system protection without requiring a board modification or any extra PCB real estate. The protection device tested is known as a PolyClamp and is offered by Electromer Corporation. Testing has been conducted on a sample of driver and receiver devices and the remainder of this brief will describe the testing and the results.

TEST FIXTURES AND ESD

Special test fixtures were constructed to replicate a PCB environment. The DS14C88’s and DS14C89A’s were mounted in standard DIP sockets. Driver output and receiver input pins were connected to a protected 9-pin D Shell connector with the PolyClamp product integrated into the connector shell. For testing, the power supply pins V+ and V− of the DS14C88 device and the V_{CC} pin for the DS14C89A device were grounded. A single positive and a single negative ESD pulse was air discharged to the connector pin which was connected to a driver output or receiver input depending upon the IC under test. The tests were repeated with the supply pins left open. The ESD pulse applied to the connector pins conforms to the IEC801.2 Standard. The energy storage capacitance is 150 pF, while the discharge resistor is 330Ω. The ESD waveform is shown in *Figure 1*.



(Source: Electromer Corporation)

FIGURE 1. Typical Waveform of the Output Current of the ESD Generator

TEST RESULTS

Ten DS14C88 Quad Line Drivers were tested with the PolyClamp product. After the ESD testing, the parts were retested on the ATE (Automatic Test Equipment) final test program to determine if the device incurred any permanent damage or any degraded parameters. The results determined that the PolyClamp protected devices could withstand ESD pulses up to 15,000V, which was the upper limit of the

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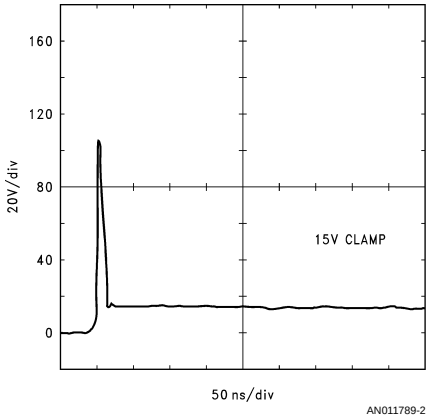
KeyTek ESD simulator. Without the PolyClamp protected connector the DS14C88's failed functional tests after a 2,000V discharge.

Ten DS14C89A Quad Receivers were tested with the PolyClamp product. After the ESD testing, the parts were retested on the ATE final test program to determine if the device incurred any permanent damage or degraded parameters. Again the results determined that the PolyClamp protected devices could withstand ESD pulses up to 15,000V. Without the PolyClamp protected connector the DS14C89A's failed at 1,000V.

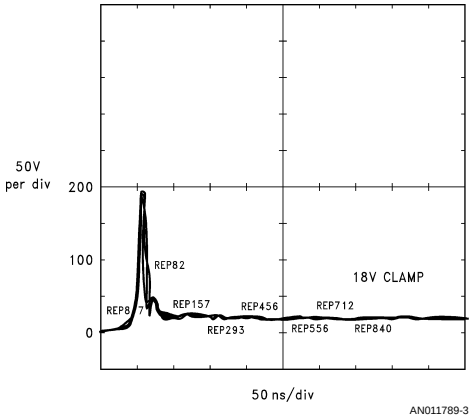
The PolyClamp product provides a high level of ESD protection to line driver and receiver integrated circuits.

Characterization testing of the PolyClamp device shows that it provides a 15V DC clamp for a 15,000V IEC801.2 ESD event (see *Figure 2*). In addition, *Figure 2* shows a typical front edge inductive spike of 100V due to test fixtures and inherent lead inductance which is similar to the performance of TVS diodes. Also, after 860 consecutive ESD pulses the PolyClamp protected connector provides the same level of ESD clamping response (see *Figure 3*). Note that the current limiting resistor (330Ω) specified in the IEC test differs from the industry standard Human Body Model (MIL-STD 883C Method 3015), which employs a 1.5 kΩ resistor. The 1.5 kΩ resistor proves a greater current limit, thus the IEC model is a more stringent test.



(Source: Electromer Corporation)

FIGURE 2. PolyClamp TVS Device Response to 15 kV ESD Pulse



(Source: Electromer Corporation)

FIGURE 3. PolyClamp TVS Device Response to 860 Consecutive 15 kV ESD Pulses

CONCLUSIONS

With the use of the PolyClamp protected connectors, protection from ESD events can easily be raised to greater than 15,000V. Additional features of the PolyClamp besides its ESD clamping capability include the following:

- Requires no PCB space — by switching the connector to a protected connector, existing PCBs can be upgraded without a PCB redesign. Many different protected connectors are offered including D-Shells and modular jacks.
- No increase in part count — the protected connector provides ESD clamping for all lines in one piece (the connector), compared to TVS diodes that typically uses 1–2 devices per signal line.
- Economical — in both cost and PCB space compared to other solutions.
- Low capacitance — the protected connector presents a 5 pF typical load to the signal line, minimizing signal distortion.

There are many different ways to protect printed circuit boards and their integrated circuits from ESD and EOS events. These include on-chip enhanced ESD protection of the integrated circuits, TVS diodes, and protected connectors, to name a few. Each of these examples has its own

merits and limitations. Enhancements to processes and the development of internal ESD protection circuits has raised integrated circuit tolerance from the several hundreds of volts in some cases to the thousands of volts, but at the expense of die size and cost. TVS diodes require additional PCB space compared to the protected connectors. These two points further illustrate the merits that the protected connectors offer. The PolyClamp protected connectors offer an extremely high level of protection, without additional PCB space, minimizes part count, and provides a *new* economical solution to increased system level ESD protection.

It should also be noted that protection capability is also offered integrated into common I/O connectors such a D-Sub, MJ, DIN, from AMP Corporation and a similar technology is available from other vendors.

RECOMMENDATIONS

The following guidelines are recommended to reduce the chance of ESD events damaging the line drivers and receivers:

a) When installing or removing the cable, power should be turned off at both ends of the system if possible.

b) Avoid physically touching the connector pins when handling the cable, and wear a ground strap when possible.

c) The use of built-in system level ESD protection devices can extend the level of ESD tolerance.

REFERENCE

For additional information on ESD see also:

Reliability and Electrostatic Discharge, Chapter 10, *Reliability Handbook*, National Semiconductor, 1987

AN-248, Electrostatic Discharge Prevention, *CMOS Logic Databook*, National Semiconductor, 1988

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