

Avoiding Electrical Overstress for Automotive Semiconductors by New Connecting Concepts

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ABSTRACT

Bosch Automotive Semiconductor Unit investigated destroyed semiconductor devices (ASIC) from electronic control unit complaints, which failed due to electrical overstress. It turned out that failure fingerprints could only be reproduced by semiconductor operation far beyond spec limits. One main failure mechanism is caused by hot plugging and bad or late ground connection. In today's cars some applications are still active for minutes after ignition switch off. So, currents of several amps are delivered and in a typical production or garage environment, hot plugging cannot be avoided completely. Bosch suggests introducing extended ground pins to get an enforced switch on/off sequence during plugging. This poka yoke protection principle is successfully used in other industries for a long time and should now come into cars.

INTRODUCTION

Bosch automotive semiconductors are used in ECUs in a large number all over the world. Some of these parts are failing and complained by the customer, normally an OEM. A high share of these returns does not indicate any Bosch process failure. This means, the ASICs were delivered in good condition and were destroyed later in a customer's process by EOS. In order to avoid these fails, it is important to understand the parts' history.

MAIN SECTION

Bosch simulated the most common fails. The idea is to destroy identical, good tested ASICs by defined electrical operation and to compare the failure fingerprints electrically and optically to the complaints.

EOS SIMULATION - For each kind of failure the respective ASIC designer developed a stress and operation model, which could create the proper failure. Then a capacitor was charged in a defined way and discharged onto the ASIC I/O pin under investigation. Nearly one thousand devices of different ASIC types were stressed and destroyed.

No failure - No part failed until being operated far beyond spec limits - without any exception.

Out of spec pulses - This is an indirect proof of out of spec pulses existing in car industry and in the field.

Robustness - The distance between spec limits and failing conditions proves the robustness of semiconductors. If this distance is shortened, this can be the reason for new fails.

Main result - Many devices were destroyed by hot plugging and an open ground connection for a short time in the beginning of the connecting process. Today's

plugs and their tolerances of pin length, contact pin position in plug, and angle between connectors during plugging often lead to a first contact of positive pins and afterwards to the contact of ground connection and vice versa during unplugging.

MECHANISM OF FAILURE - In the first short period of time of plugging without ground connection in plug, it is possible for the ECU supply energy to go down to ground along a signal line into a different ECU, overloading and destroying semiconductor structures. Often buses, especially CAN, are destroyed.

Interaction - So, connecting ECU x into a car may destroy ECU y by hot plugging. Clarification is nearly impossible, especially, if x and y are competitors.

HOT PLUGGING IS SYSTEMATIC - Immediately after switching off ignition there are still currents of several amps in wiring harness decreasing to several hundreds of milliamps for minutes. The total current never is zero in that time. "Ignition off" does not mean "current off". Opening a connection during that time, you cannot be sure not to interrupt a current. So, you have a systematic hot plugging situation, which can not be avoided by regulations or paperwork.

POKA YOKE PROTECTION - Because the destroying pulses are neither known nor specified, no effective protection by devices is possible. The only poka yoke solution is to extend ground pins.

New standard - Interactions between ECUs in a car enforce ground pin extension of each ECU and each plug in car, which supplies energy for ECU. So, one needs a new standard for wiring harness.

Chances - I/O protection within ECU may be eased, because critical pulses are away and so additional protection may be redundant. This is to be investigated. Furthermore connectors may become cheaper, because the extended ground pin at the same position in plug may help to reduce the number of connector variants.

Benefit - The OEM profits by each single not failing ECU. Extending ground pins first of all is a measure to optimize the OEM and not only the suppliers.

Implementation - The OEM needs to specify extended ground pins in his requirements. Implementation only works top down and makes most sense with new products. Changing existing connectors may be too costly and too complex.

EOS Awareness - Today in car industry ESD more or less is well known. Not so with EOS, which is often mixed up with ESD and failures due to EOS are assigned to suppliers alone. But clearing up failure root causes out of interacting systems only works together, supplier with OEM. Therefore a better awareness for EOS in car industry will help clarifying and avoiding fails.

CONCLUSION

As Bosch shows, many failures in car industry and field result from EOS by not specified pulses. Often the reason is hot plugging, which cannot be avoided completely in modern cars. The only poka yoke solution is to build up a secure ground reference during plugging by extension of all involved ground pins. This principle is used successfully for a long time in telecommunication industries, in mains plugs in houses, in on board diagnosis, and in USB2.0. In upcoming high power electrical cars it will become even more important. On the way to zero defect, ground pin extension is essential to avoid many complicated failures of car electronics.

ACKNOWLEDGMENTS

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REFERENCES

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

ASIC application specific integrated circuit

ECU electronic control unit

EOS electrical overstress;
operation out of spec: powerful pulses able to destroy a greater part of the semiconductor area

ESD electrostatic discharge: pulses with very high voltages in range of several thousand volts, but with very low power. They only can destroy parts of a single semiconductor, but never will lead to molten areas.

Hot Plugging Plugging or unplugging under voltage

OEM original equipment manufacturer: a vehicle manufacturer