# Contact Testing for Reliable Car Electronics

## White Paper

by Ben Haest & Roman Bertschi

# Content

# About the Authors

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# Introduction

Modern electronics systems, whether found in industrial, medical, automotive or other applications, are continually evolving to include additional functionality, to cram more components into a smaller space, and to provide better reliability for fast access to the most accurate data.

Regardless of the environment, in most cases the information transfer is happening at a breakneck pace and testing these advanced systems to ensure data integrity becomes paramount, since a system is only as reliable as its weakest data packet. If information is lost or delayed, the whole system can quickly fall apart.

Critical area where human safety is paramount, is in the modern automotive industry, where reliable component function is a top priority. The increasing number of electronic components present in today's cars not only need to coexist, but they need to operate autonomously from some and in conjunction with others without impeding safe operation while withstanding a multitude of harsh environmental factors over an extended period of time.

For example, over the lifetime of virtually any car, some lasting more than 300'000 km, the electrical contacts within a connector have to withstand vibrations, heat, cold, humidity and dust under many different conditions.


Autonomous Driving - The reliability and safety depends on correct sensor information.

# Ensuring a Car's Connections

Since electronics have entered the automotive scene, several standards for testing of electrical contacts have been developed. The aim is to design and to manufacture reliable connection systems between the different control and peripheral units within a vehicle. Reliability is of utmost importance to assure the proper functioning of the ECU (Engine Control Unit), ABS, ESP and airbag systems to name a few.

In the early days of testing, when the first electrical contacts were being incorporated into a car, they only carried the current for headlights and other basic components. Nowadays, additional signals, such as audio, HD TV, phone, radar, image recognition and GPS, are passed through the contacts of multi-pole connectors along with the critical operating signals. In addition, many of the actual signals are high frequency and low current, so they demand especially stringent testing criteria.

For each environmental parameter – vibration, temperature, dust, humidity, etc. – different standards, typically conducted in a laboratory, have been developed to simulate the damaging influence of the environment on the quality of the electrical contacts during a vehicle's lifetime.

## The Testing Process

A complete test specification will define the level, frequencies or shock level and test time for the excitation vibrations on a shaker table and the simultaneous temperature cycles in a climatic chamber. In a typical automotive test, the connector is set up in exactly that way. The combination of the simultaneous environmental parameters – vibration and temperature – is more rigorous than two separate tests with only one environmental condition, while being both more realistic and more time efficient.

The automotive standards also accurately define how the connector should be mounted onto the shaker table. Because the cables are mounted to the connectors, the different electrical contacts are also heavily mechanically stressed through vibrations that come through the cables as well. Of importance to note is that the connectors and cables must be fixed in a very specific way to ensure tests repeatability and guaranteed comparable results.

A common test specification in the US is SAE/USCAR or the specification GMW 3191 from GM. In Europe, especially in Germany, a common test specification is LV214. These test specifications refer to the DIN IEC 60068-2-(6, 64, 27, ...) for sine, random and shock excitation and the DIN IEC 60068-2-14 for the temperature excitation while DIN IEC 60512-1-1 specifies the visual inspection during the test procedure.

A typical electrical test specification is the contact interruption criteria of 7 Ω and 1 µs with a maximum current of 100 mA. As described in the standards mentioned above, the 100 mA current is obtained from a 12 Vdc voltage source and a resistor of 120 Ω. An interruption is detected by monitoring the voltage across the 120 Ω resistor. However, the technology has evolved dramatically since the first versions of the norms and standards have been published. With the actual digital measurement systems, it makes more sense to monitor the voltage across the electrical contact and to detect any interrupt condition directly from this signal. Such test strategy also offers more flexibility to fulfill different test requirements: different interruption times with different contact resistance levels as well.

Especially with the development of the electrical cars, some electrical contacts carry much higher currents than before. Contacts that carry very high currents are tested with a constant current source of 10 A. This current comes from an electronic device, so there is no resistor anymore to pick up a reference signal to detect an interruption. To cope with the actual testing demands a flexible way to define the trigger conditions, interruption time and contact resistance, is highly needed.

In addition, many car manufacturers adapt some of the standard specifications to their own requirements. With respect to the contact coating (Zn, Ag or Au) the contact resistance requirements are different and with respect to the place where the connector will be mounted into the car, especially the vibration levels and the temperature test profiles are very different as well. So, also the measurement equipment needs to cope with all different test requirements.

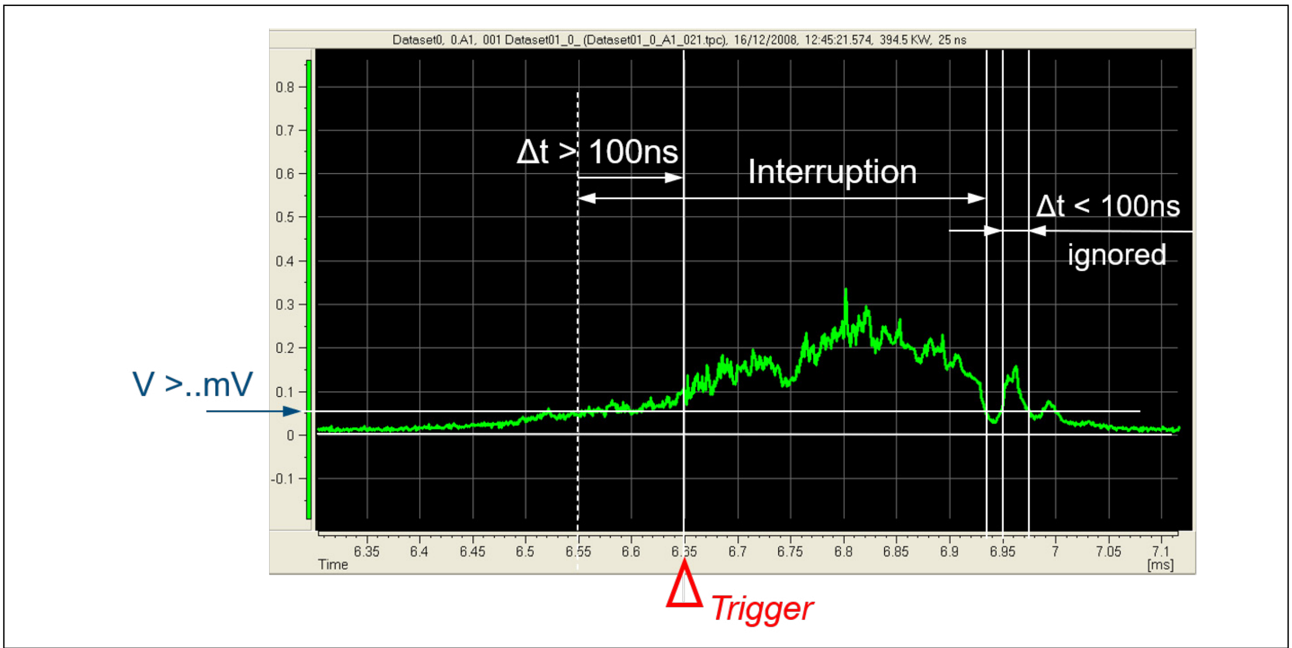
Typical signal during a contact interruption

# The Trigger Level

The trigger level of 7 Ω is not a random number and is not a standard value for a commercially available resistor. It is a well-chosen value, based on experience and based on the observation what happens during a contact interruption.

The moment the contact opens, when both metal parts of the contact do not make physical contact anymore and there is no pressure to keep both parts together, the contact resistance is about 7 Ω. Depending on the type of contact etc. this value can be different of course, but is a well-chosen value. Still, some standards, like the DIN IEC 60512-2-5 or the ISO 8092-2 specify the open contact level at 50 % of the supply voltage with eventually much larger interrupt times, especially for relay contacts which also show a lot of bouncing. At the end, it is the design engineering department that defines the test specifications.

The most extreme trigger conditions are given by FlexRay: 1 Ω for 100 ns, just to complete the whole pallet of requirements that can be demanded for a test.




The trigger condition is defined by level and length of the interruption

## Data Acquisition Systems


QED GnΩstic64

Elsys TraNET EPC

## Data Acquisition Requirements

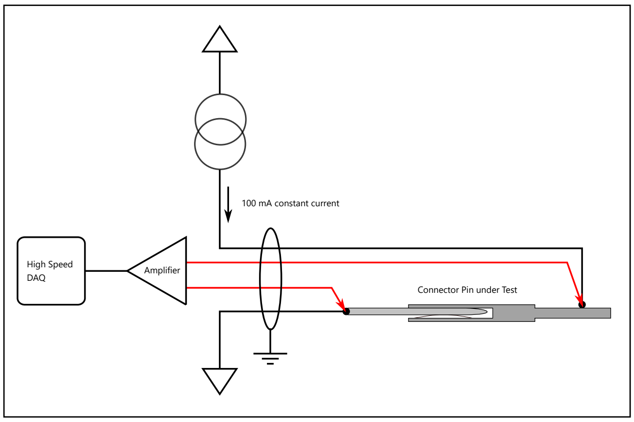
In the distant past, a number of test systems have been developed, just showing a red or green light when an interruption of the contact had been detected or not. As the measurements occur in an EMI (Electromagnetic Interference) very noisy environment, due to the shaker system with or without a climatic chamber, it could not be proven that no noise peak instead of an interruption had been detected.

The OEMs (= car manufacturers) demanded a solution where the time data of the measured signals during the interruption(s) was stored. The time data proves if indeed, an interruption had been measured or a noise peak disturbed the measurements.
The design specifications of a proper measurement system are very demanding. Just a short list as reference:

- Noise free measurements with a very high bandwidth (DC to max. sampling rate)
- Very high sampling rate for each channel
- Flexible programmable trigger conditions
- Each channel must operate as an independent transient recorder
- All data must be saved on hard disk during acquisition

For more than 15 years, the Luxembourg based company QED S.A. (Quality Electronics Design S.A.) uses the Elsys' data acquisition cards to build the GnΩstic64 system for the reliable contact testing. Based on the know-how and the experience of both companies, a new PCIe data acquisition card has been developed. The new card, referred to as TPCE-GN, incorporates an electronic stable constant current source of 100 mA and a high impedance symmetrical input amplifier. The new card includes the proven Elsys' signal data processing technology up to 40 MS/s or 80 MS/s.

Below the schematic setup of the contact measurement is shown. Because the current source is constant, the voltage across the contact is proportional to the contact resistance. As a consequence, the measured signal can be reported directly as the contact resistance value in Ohm (Ω).




Schematic Test Setup

TPCE-GN 8-Channel Data Acquisition card with integrated constant current supply

# Event Controlled Recording

Measurements with 40 channels at 80 MS/s sampling rate procures a data stream of 6.25 GB/s which is not processable. For that reason, the high sampling rate only starts at the trigger event, independently for each channel, while a second low sampling rate is maintained for all channels (= dual mode). The signals, measured with the low sampling rate, are used for the trend analysis of the contact resistance.

The time signal of the detected interruption is stored directly onto a solid-state drive (SSD). This recording mode is called "Event Controlled Recording", short ECR.

The actual measured signals are constantly written into the on board ring buffer. Subsequently, each trigger event marks the range where the signal data will be read from the ring buffer and finally copied to the file on the hard disk.

## ECR Single-Channel

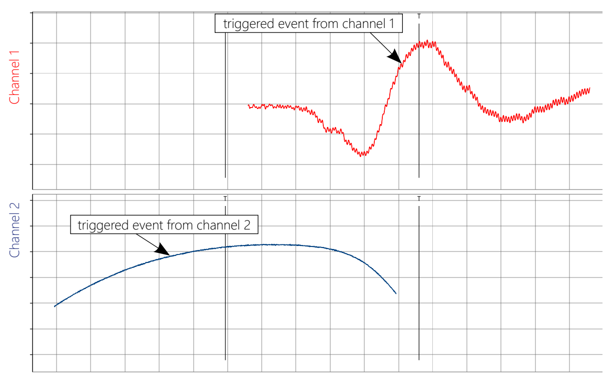
In this application, where several contacts with no physical relation to each other are tested, the ECR Single-Channel mode assures that only the data of the triggered channel is stored. This way, a big amount of data space can be saved as only the relevant data is stored. During data storing of one channel, the system remains ready for the high-speed data acquisition of an eventual micro-second contact interruption on all other channels. Each channel can essentially operate as an independent transient recorder.

## Dual-Mode

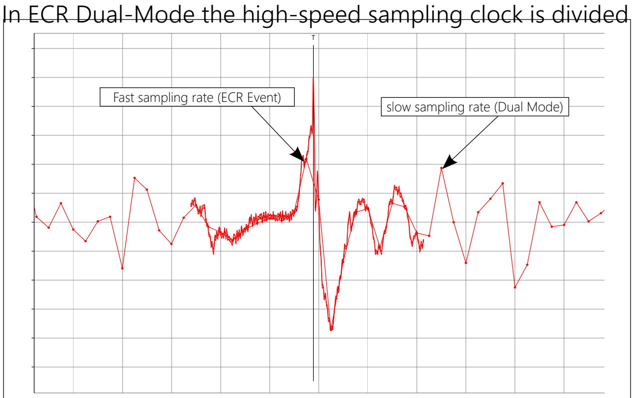
In addition, ECR offers a mode called "Dual-Mode". This parameter in ECR defines a second sampling rate, to measure and to monitor each signal during test. Typically, the contact resistance shows a higher value during the high temperature cycle while the contact resistance reduces at low temperatures (in automotive down to -40 °C).

In ECR Dual-Mode the high-speed sampling clock is divided by a specific parameter to obtain the low-speed sampling rate. Some customers require only one measurement per minute for monitoring, but it makes sense to define the low sampling rate at 1 Hz. In a standard 40 MHz system the dividing factor then will be $4.0\ e10^{7}$.
Using the dual mode strategy, continuous testing of all signals for monitoring and acquiring the fast phenomena can go on for a very long time without filling up the hard drive.

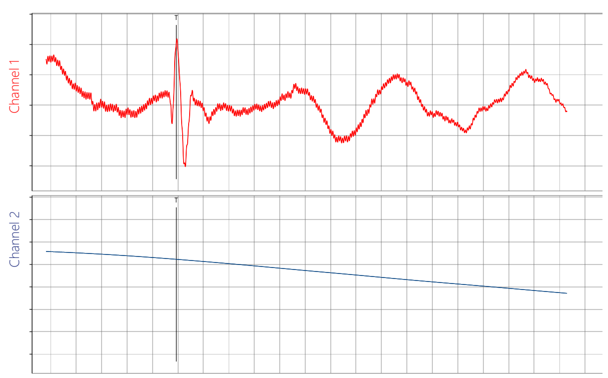
For contact testing, channels can be "associated" with other channels. This makes sense to link e.g. a temperature measurement channel and a frequency measurement channel (during sine excitation) with the contact channels. As a consequence, when one contact channel triggers, due to the event of an interruption, also the temperature and the frequency channels will be triggered. After the test has been finished, this will allow to investigate the correlation between the number of interrupts and the according temperature or frequency.




**ECR Single-Channel** - Each channel is triggering independently from the others.



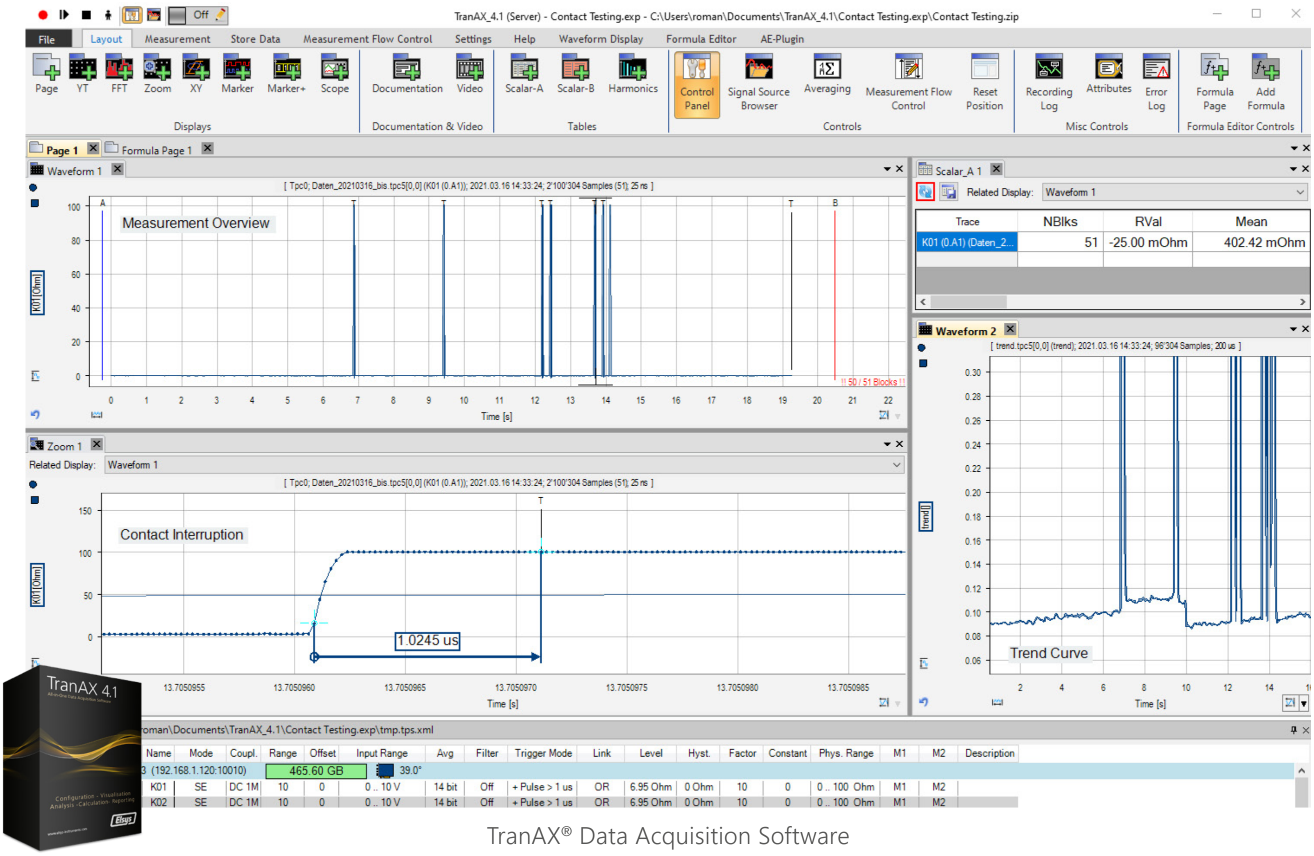

**ECR Dual-Mode -** Fast ECR events overlapped with the slow dual mode measurement.




**ECR Multi-Channel** - Trigger condition on one channel will trigger all other channels too.

## DAQ Software

Often measurements are made with more than 8 channels and over a longer period of time. In order to get an idea of the status of the test, a powerful data acquisition software is a great advantage. Since each channel has to be evaluated individually, a flexible display in which the channels are shown separately is important. The data acquisition software TranAX® meets these requirements. In addition to the visualization of the measurement data, the hardware settings are also made here. Using an experiment hierarchy, predefined measurement processes can be prepared and reloaded at any time. The integrated formula editor can also be used to program your own evaluations and, if necessary, exported to MS Excel®.

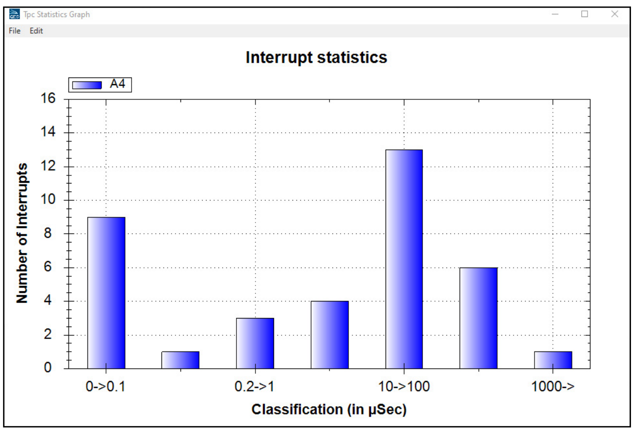



TranAX® Data Acquisition Software

## Analysis Software

The analysis software reads the recorded data of the micro interruptions, calculating a statistical evaluation of the interruption times for every single contact. The results are graphically presented and stored in a text file that can easily be imported into Excel for a more in-depth analysis or test report generation.

The analysis software empowers the user to change the amplitude of the trigger level in post-processing, in turn providing the possibility of evaluating the data according to different norms. In addition, for each channel, the elapsed time of each interruption is calculated. A graphical statistical analysis of the micro interruption according to the excitation frequency of the shaker and the environment temperature is immediately available on the screen.




Interruption Statistics Analysis

## Conclusion

Electrical contacts are essential in the development of more secure and intelligent car systems. In order to fulfill the test requirements specified by the car manufacturer a corresponding measurement system is needed.

The solution shown in this paper is a powerful tool for all contact manufacturer or testing laboratories. The high number of parallel usable channels makes it suitable for testing high pin-count contacts in a reasonable amount of time. The system based on a general purpose data acquisition system, gives the most flexibility for adapting the test settings on manufacturer specific requirement or future standards.


Are you interested in learning more about reliable contact testing and the GnΩstic64 Data Acquisition system?

Feel free to contact us for further discussion.

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