Diagnostic routines for automotive relays in the field, IC- and EOL-tests

Introduction

With the increase of electronic circuits and safety requirements in cars, more and more switching contacts are monitored by diagnostic routines. Similar routines are used by the system suppliers before, during and after the assembly processes (**I**n-**C**ircuit and **E**nd-**O**f-**L**ine tests) as well.
Automotive relays are originally designed to switch real automotive applications (e.g. motors, lights, heatings, etc.) with a load voltage of 12V (or 24V or 42V) and load currents above 1A. Lower diagnostic current and voltage levels can result in wrong interpretations of the state of the relay contact.
This paper explains the technical background of the relay contact system, coil system and dynamic behaviour and gives recommendations for applicable diagnostic routines.

Contact system

The most common contact materials for automotive relays are finegrain silver (AgNi0.15) and silver tinoxide ($AgSnO_2$). Both materials are affected by sulfidation and oxidation. These layers of oxides, sulfides and other compounds will be formed on the surface of metal-contacts by absorption of gas molecules from the ambient atmosphere within a very short time. The layers will increase the contact resistance. The resistance of such layers depends on the thickness of the layer, effective contact area and the specific resistance of the contact material/layer. To get a reliable electric contact these layers have to be destroyed. This can be done by mechanical, electrical or thermal destruction.

A mechanical destruction requires high contact forces. With the very high degree of miniaturization of automotive relays, those contact forces cannot be safely achieved, especially for normally-closed contacts.

An electrical destruction requires a specific breakdown voltage and current. This destruction process is called **A-fritting**. The breakdown voltage depends on the thickness and specific resistance of the layer and can reach theoretically some hundred volts. In the practice of automotive relays the breakdown voltage can be up to 3V. A current of min. 10mA is needed to start the A-fritting.

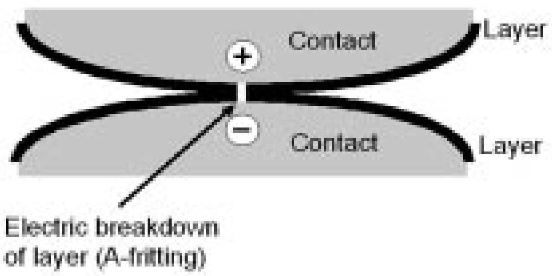

Fig 1: Contact layers

After the electrical breakdown a small current is forced through very thin channels in the layer. The resulting local high current density, heats the conducting channels up quickly, destroying the layers, until finally (within a few ms) a metal to metal bridge is established. This process is called **B-fritting**. The B-fritting voltage depends again on the thickness and specific resistance of the layer and can reach in the practice of automotive relays up to 300mV.

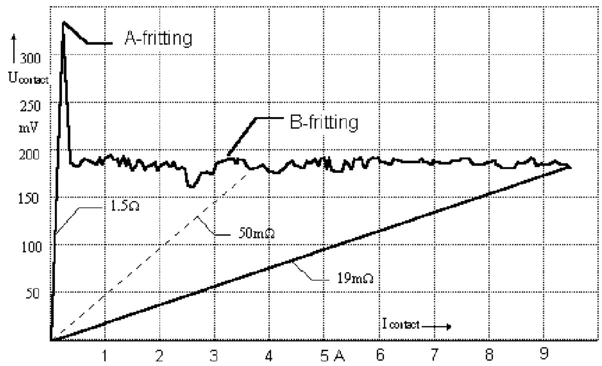

Fig 2: Fritting of a relay contact

A thermal destruction requires high temperatures, which will only be generated by high contact currents or electric arcs (disconnecting inductive loads). The thermal destruction can only take place, after an electrical destruction.

Coil system and dynamic behaviour

Automotive relay coils are designed for DC-voltages. The switching times (i.e. operate time or switch on time and release time or switch-off time) are usually in the low millisecond-range. The operate time depends on the applied coil voltage. The graph below shows the relation of the operate time and coil voltage, related to the actual pull-in voltage. The nominal voltage in the displayed case is 170% of the actual pull-in voltage at an ambient temperature of 23°C (e.g. 7V pull-in voltage at 12V nominal voltage). Higher coil temperatures increase the pull-in voltage and subsequently increase the operate time at same applied coil voltage. Including possible contact bouncing, the operate time can be triple as high as the typical values shown in the datasheets.

Operate time versus coil voltage

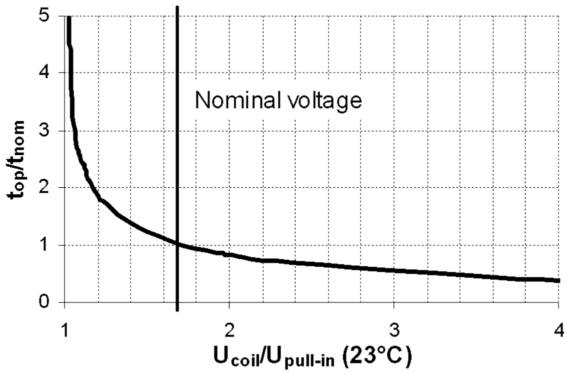

Fig 3: Operate time

The release time depends mainly only on the used coil suppression (see also application note: “The application of relay coil suppression with DC relays”). A low ohmic device (e.g. a diode) in parallel to the relay coil can increase the release time by a factor of up to 4 compared to the typical values shown in the datasheets.

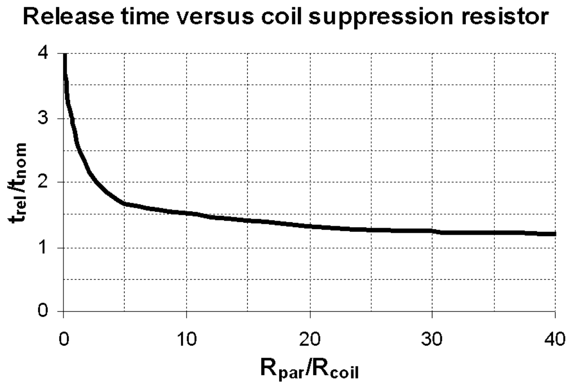

Fig 3: Release time

Coil resistance

The inductivity of automotive relay coils can exceed (in the unsaturated range) 1H. This results in time constants *tau* between 1 – 50ms for the exponential inductive current increase (jump response). If the ohmic coil resistance is measured with a 4-pole measurement, the resistance value will be wrong, if it is measured during the inductive current increase after switch on.

Recommendation for diagnostic routines

A contact diagnostic routine must

➔ **take into account, that the contact resistance may be non-linear.**

Due to the explained fritting phenomena, the contact resistance can be non-linear. This means, that the contact resistance, measured at low voltage and current levels (e.g. standard multimeter) can be significantly higher than the contact resistance under real conditions (e.g. supplying a 100W load).
We recommend to perform the diagnostic routine with the real application and real boardnet voltage connected.

➔ **supply a sufficient voltage and current to force the A-fritting**

If the diagnostic routine cannot be performed with real application and voltage, the measurement voltage and current level must secure an electrical breakdown of possible layers.
We recommend a voltage of min 5V and current of min. 100mA.

➔ **accept, that the voltage drop can be 300mV**

The B-fritting is a physical phenomenon, which can occur on all silver contacts. For signal-applications, special signal relays are available.
We recommend to set the diagnostic threshold voltage to 500mV <u>per relay contact</u>
(important for H-bridges or serial contact arrangements).

➔ **regard the maximum possible switching times**

If the status of the contact has to be changed for the diagnostic routine (energize or de-energize relay), the routine must wait until the intended contact status is reached. Depending on ambient conditions (temperature, voltage levels, coil circuits) the times can be significantly longer than the specified typical times.
We recommend a delay time of min. 10 times of the typical switching times.

A coil diagnostic routine must

➔ **secure, that status of the contact does not change during the diagnostic.**

If the coil driver is monitored by a watchdog routine, the energizing/de-energizing time of the coil must not result in an unintended closing or opening of the contacts.
We recommend to use watchdog times of max. 0.5ms.

Remarks:

1) During the lifetime of the car, the relay parameters can alter due to ageing processes like contact erosion, fretting corrosion and relaxation. Moreover the environmental requirements (temperature, vibration, etc.) in the car are higher than in IC- or EOL-tests. Therefore we recommend for diagnostic routines in the car a higher threshold voltage (appr. 3V) and higher delay times (min. 15 times of the typical switching times).
2) Most of the applications, switched by relays, are not safety related. If a potential relay failure is detected, in these cases we recommend to not block any further activation of the relay. Instead we recommend to write the occurence only into the error memory.