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Remplacement des relais dans les voitures : contraintes et avantages du passage de la solution électromécanique à l'approche intégrée

Replacement of Relays in the Automobile: Constraints and Advantages concerning the Conversion of Electromechanical Devices to Silicon Switches

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Abstract

This paper presents a family of intelligent ultra low R_{DSON} power switches replacing electromechanical relays in the car. This approach removes fuses and reduces wire harness complexity with a significant system cost savings. The paper explains how the Power QFN (PQFN) package with multiple chips reduces board space, reaches R_{DSON} of 2mΩ, provides very low thermal resistance and brings intelligent features to increase system reliability.

1. Introduction

Motorola Semiconductor Products Sector at Toulouse (France) develops integrated solutions to replace electromechanical relays, fuses and discrete circuits in automotive power management applications. This family of products is designed for harsh environments and fulfils automotive requirements (maximum ratings 41V, 15 years lifetime, etc).

The main disadvantages of the electromechanical relay are humidity susceptibility, contact malfunctions and corrosion over-time. Silicon switches resolve these issues. The new 2mΩ smart power switch [1] revolutionises power distribution to integrate very low On-resistance (R_{DSON}), self-protection, full diagnostic capability and flexibility.

2. Automotive Power Management Requirements

Automotive vehicles require protected load control ranging from power-train management system to body functions, such as electric seat and window lift. High currents are driven to correspond to the load requirements: bulbs, motors, solenoids, etc.

Feature	DC current needed
Door locks	1 to 2A
Window lift	7 to 12A
Lighting	15 to 25A
Electric seat	10 to 30A
Power switching	10 to 40A

Table 1. Typical automotive current requirements

All of these applications currently use relays and vary in size depending on the load current. The number of relays used in a car ranges from 30 relays for a small vehicle to more than 80 for a high-end automobile. Today, three types of relays are available: electromechanical; discrete silicon switch; and integrated silicon switch (smart power switch). In a system with relays, fuses are used to protect power management in case of short-circuits.

The goal is to reduce the number of fuses in new generations of vehicles. Discrete switches combined with external circuitry or smart power switches provide non-destructive protection. However, smart power switch combines power management capability and more intelligence in a single device, allowing board space reduction. Silicon integration offers smart features, such as slew-rate control and configurable fuse functionality.

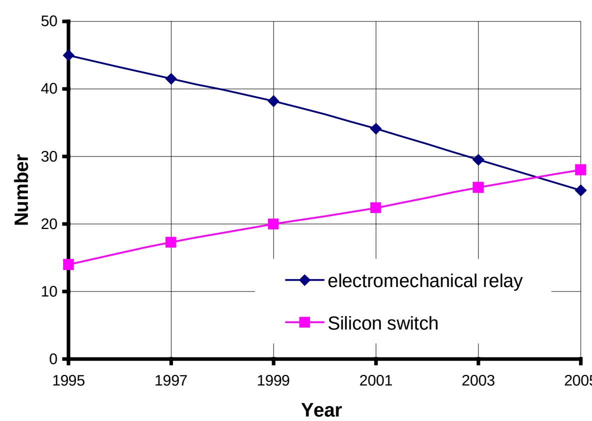

Figure 1. Penetration of Silicon switches in automotive applications

Currently, integrated smart power switches replace electromechanical relays only for low current applications (<10A DC) [2]. For higher current requirement (>20A DC), the available solutions require discrete power MOSFETs with external circuitry for short-circuit protection and limited diagnostics.

The “2mΩ” smart power switch pushes integration one step further with high-current capability (60A DC).

3. Smart Power Switch Solution

A dual-die solution with HDTMOS™ and SMARTMOS™ technologies leads to an optimised solution.

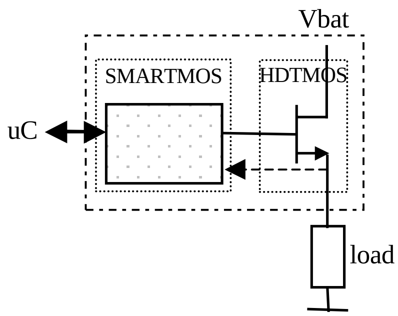

Figure 2. Multi-chip partitioning

3.1 High-current switching

The HDTMOS™ technology offers ultra low R_{DSON}. This technology is based on a vertical TMOS sustaining 45V. The initial target application required 5.5W @ 150degC maximum power dissipation for 40A DC current . This leads to 3.4mΩ R_{DSON} max @ 150degC and 2mΩ max @ 25degC. A significant advantage of Motorola's HDTMOS™ technology is a lower R_{DSON} deviation in temperature.

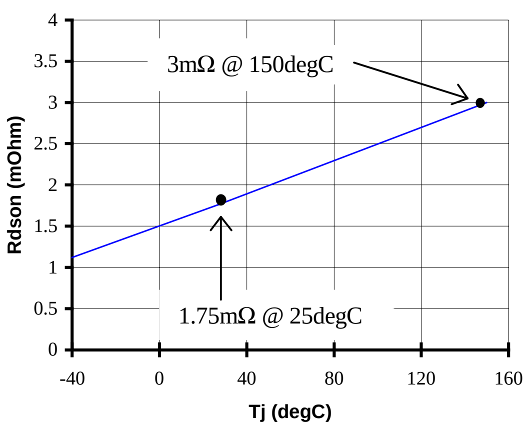

Figure 3. R_{DSON} deviation versus temperature

The PQFN [3] package has been developed to provide low thermal resistance (1deg/W) and multi-chip capability. Smaller package size ($12x12mm^2$) saves board space. Therefore, the package could be located inside power connectors or at the actuator.

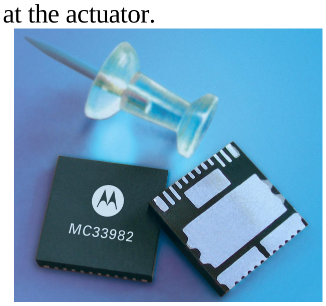

Figure 4. PQFN 12x12 package

3.2 Intelligence integration

The SMARTMOS™ control die provides the added intelligent features (operating voltage 6V to 27V). This technology combines high-density integration, high-speed logic capability and high-voltage analog functions.

The device is fully protected in case of over-temperature, over/under-voltage, reverse battery (-16V), load missing, ground disconnect and/or short-circuit.

With an innovative appoach to manage over-current, external fuses can be removed and wiring harnesses can be optimised.

Fully configurable features allow the control of multiple load types. This capability increases system reliability. Current level detection threshold and transient reponse are programmable. Two over-current detections are available: severe short-circuit protection (OCHI: 150A or 100A) and soft short-circuit protection (OCLO: 8 programmable levels from 15A to 50A). Four programmable blanking time windows are available to better control transient current behaviour (from 150us to 150ms). After an over-current event, the external microcontroller can decide to switch "on" the load current again without any physical device change requirement.

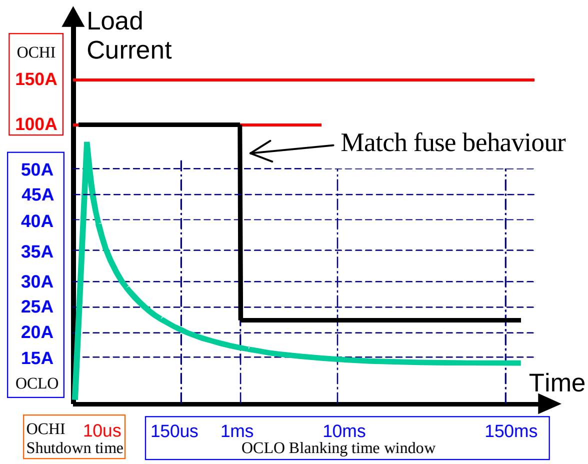

Figure 5. Configurable over-current protection

A microcontroller (MCU) can configure and drive smart power switch through an 8-bit serial peripheral interface (SPI). The SPI allows the MCU to configure the device or to diagnose service problems. An analog output current feedback is available to monitor load current in real time. Slew rate is adjustable through the SPI to reduce electromagnetic emission for EMC or provide Pulse Width Modulation (PWM) capability. This communication interface, associated with daisy-chain capability, minimises the number of interconnections required between the MCU and several smart power switches.

A turn-on delay functionality is available to reduce the inrush current when several heavy loads are activated from a single microcontroller command.

Internal watchdog circuitry provides an additional safety feature; when watchdog timeout is reached, a failsafe mode allows to force output state.

A wake function forces the device into a sleep mode with minimum standby current consumption (less than 5uA).

4. Conclusions

This paper presents a smart power switch solution which allows for improved power management. The multi-chip concept and PQFN optimised power package lead to the first intelligent 2mΩ R_{DSON} switch with high-current capability (60A DC). Daisy chained SPI configuration increases flexibility to drive bulbs, motors, solenoids, etc. Self-protection and full diagnostics are also key attributes of this device. The PQFN package provides low thermal resistance (1degC/W), good reliability and cost savings.

Samples have been shown to demonstrate 100A peak capability in an automotive application [4].

This solution will also be implemented for applications requiring dual or quad smart power switches and fast switching capability (40kHz).

With this innovative approach of the embedded system (automotive, aircraft, marine, etc), smart power switches are leading to a new definition of power distribution architecture. Suppression of fuses, optimisation of wire harnesses and further board space reduction are therefore achievable.

For further information, please contact Philippe Dupuy (philippe.dupuy@motorola.com).

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