PROJECT RESULT

Enabling
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T124: High operating temperature systems on chip, assembly and reliability (HOTCAR)

In-car electronics ready to take the heat

The automotive industry is turning increasingly from purely mechanical to electronically controlled systems for a growing range of functions related to vehicle management, safety and comfort. In order to contain manufacturing costs, it is also moving to complete pre-assembled modules with increased functionality such as engine/transmission units. Any electronics integrated into these assemblies must be capable of reliable operation at sustained high temperatures. HOTCAR made significant progress in developing affordable silicon technology for in-car and other demanding industrial applications.

Electronics are replacing mechanical and hydraulic systems for many functions in vehicles – from engine management and emissions control, to braking, suspension and air-bag actuation. Increasing levels of efficiency, safety and comfort will be accomplished by advances in circuit complexity.

Carmakers also face rising consumer expectations in a highly competitive market, while being forced to reduce production costs. This is achieved by assembly optimisation – for example moving to engine/transmission assemblies delivered as fully tested and calibrated units including electronics, sensors and wiring ready for installation.

Harsh environment

Placing electronic control units (ECUs) directly onto an engine, into a transmission or near brake disks represents an evolutionary step from distributed mechanical systems to functional integration of mechanics and electronics to form mechatronic systems. Weight and space limitations demand higher integration, especially in small city cars, which are also the most cost-critical. They also limit cooling possibilities. These factors, together with increased self-heating of devices and modules, feed the demand for higher temperature operation. Electronic controls incorporated into mechatronic modules must be capable of surviving long-term operation in a harsh environment, where humidity, vibration and high temperatures substantially affect reliability. Similar or even worse conditions are faced in sectors such as oil-well drilling.

For this to be feasible, carmakers need components specified for operating temperatures up to 165°C or higher. Applications will be implemented using components capable of operation, in some cases, even beyond 200°C. Major growth in high-temperature (HT) electronics is likely to be in engine, transmission and braking/traction control as well as steering. Mass production of new devices able to meet the high standards of robustness, temperature stability and lifetime required will reduce cost and promote penetration into the high volume markets.

Ambitious targets

While the temperature limits for state-of-the-art engine and transmission controls are 125° and 140°C respectively, MEDEA+ T124 HOTCAR targeted 150 to 200°C. For oilfield equipment, the limit was 225°C. The challenge was to achieve these goals with innovative yet inexpensive solutions. This forced a focus on extending existing silicon technology, rather than investigating more exotic and expensive materials. Also, as a comparatively small part of the global market, development of specialised HT products called for standardisation at all levels. Only when carmakers work alongside system suppliers to define future environmental conditions precisely and build a common requirement platform does it becomes possible for chipmakers to deliver reliable components working at the desired temperatures.

Siemens VDO Automotive therefore established a consortium that embraced the whole supply chain vertically, while also fielding horizontal strengths through the collaboration of leading European chipmakers – Infineon, STMicroelectronics and ATMEL – as well as systems manufacturers Conti Temic, Schlumberger, Siemens and Valeo.

Two platforms

The specific objective was to realise microcontroller (μC) and application demonstrators differing in performance, functionality and application temperature: this included an eight-bit μC for a higher temperature level and limited complexity; and a 32-bit μC for more complex control tasks at a lower temperature level (>150°C).

Two approaches were adopted:

1. Adapting established silicon technology to volume needs. Standard designs and technologies were re-used as far as possible to keep costs down. Existing building block libraries were optimised for the HT environment. New test methods and equipment were explored. An eight-bit μC in temperature-tolerant CMOS (ttCMOS) technology was fully characterised and qualified up to 225°C.
2. Investigating HT-specific technologies aimed at high-end, mid-/low-volume markets and extreme environments. This entailed developing and qualifying μC design and processing in silicon on insulator (SOI), and adapting bipolar-CMOS-DMOS (BCD)/ smart-power technology. A 32-bit CMOS μC in flip-chip and environment-friendly (lead- and halogen-free) versions was qualified for HT applications. It operated completely within the specified functionality range up to 170°C. Enormous potential for chip-area reduction was identified using SOI instead of BCD technology.

Convincing results

Plastic mould compounds, organic substrates and lead-free assembly were developed and qualified for automotive and oil industry needs. And lead-free soldering was demonstrated as applicable up to 150°C. A qualification method was developed taking into account dominant failure mechanisms on individual system levels. Partners were supported in demonstrator production by the availability of many HT-reliable components.

Five functional demonstrators were designed, assembled and tested. EPS, Siemens VDO and Valeo worked on real application ECUs, with HT testing close to product qualification. CRF and Conti Temic developed specific test boards, mainly focusing on thermal shocks and HT storage. No component developed failed under the rigorous test procedures. As a result of HOTCAR, partners have acquired and shared broad knowledge of HT behaviour and needs. This will contribute to leaner, greener cars. It could help the European electronics industry to secure an increased share in markets predicted to reach over €440 billion for cars (and over €130 billion for oil-well equipment) by 2008.

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AT&S
C-MAC
Conti Temic
CRF
DaimlerChrysler
HARTING
IMOMEC
Infineon
Isola
Schlumberger (EPS)
Serma Technologies
Siemens
Siemens VDO
STMicroelectronics
Valeo

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KEY PROJECT DATES:

Start: December 2001
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