Technical Report

on the

Concept Study

of a

Safety Architecture

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Report no. TF85875T
Revision 1.0 of 2014-06-18

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Revision history

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<td>1.0</td>
<td>Initial</td>
<td>2014-06-18</td>
<td>M. Ramold / W. Velten-Philipp / G. Neumann</td>
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*Table 1: Revision history*
1 Target of Evaluation

In June, 2011 Texas Instruments Incorporated requested TÜV SÜD Rail GmbH to participate at a concept study. The Project No. related to this Technical Report was as follows: 717505473.

1.1 Scope of Testing

Target of the concept study is to evaluate if it is feasible to reach an equivalent risk reduction of category 3 according to EN ISO 13849-1:2008 with a safety architecture consisting of a microcontroller device with on-chip safety integrity measures and an external supply and monitoring device. An overview of the principle Safety architecture is shown in figure 1.

![Diagram of safety architecture]

Dashed lines represent measures to detect faults

Key
- \( i_m \): interconnecting means
- \( c \): cross monitoring
- \( I_1, I_2 \): input device, e.g., temperature sensor
- \( L \): logic, e.g., MCU
- \( TE \): test equipment, e.g., intelligent watchdog
- \( m \): monitoring
- \( O_1, O_2 \): output device, e.g., relay

Figure 1: Block diagram of safety architecture

The safety function is executed by a microcontroller. The microcontroller has on-chip implemented safety integrity measures. Furthermore the microcontroller is monitored by external test equipment / external device. The intended safety architecture does not comply with the designated architecture according to EN ISO 13849-1:2008 for category 3. Therefore a concept study was set up to evaluate if it is feasible to reach an equivalent risk reduction of category 3 according to EN ISO 13849-1:2008.

1.2 Basis of the evaluation

The concept study was based on the documents listed in clause 3 of this report.
2 Basis of Evaluation

The regulations and guidelines which form the basis of the type testing are listed below.

2.1 Functional Safety

<table>
<thead>
<tr>
<th>No.</th>
<th>Standard</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>[N1]</td>
<td>EN ISO 13849-1: 2008 (Category 3)</td>
<td>Safety of machinery - Safety-related parts of control systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 1: General principles for design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>safety-related systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 2: Requirements for electrical/electronic/ programmable</td>
</tr>
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<td></td>
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<td>electronic safety-related systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13849 -</td>
</tr>
</tbody>
</table>

*Table 2: Functional Safety*
3  Documents provided for review

The following documents were provided by Texas Instruments Incorporated:

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Document-No./ File identifier</th>
<th>Revision</th>
<th>Date</th>
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<tbody>
<tr>
<td>[D1]</td>
<td>ISO13849 Safety Analysis</td>
<td>ISO13849 Safety Analysis v0.15 Draft.xlsx</td>
<td>0.15</td>
<td>2014-03-27</td>
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*Table 3: Documents provided for review*

4  Performance and result of tests

4.1  Test reports

Following test reports were issued by TÜV SÜD Rail GmbH or other accredited test laboratories.

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Document-No./ File identifier</th>
<th>Revision</th>
<th>Date</th>
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<tbody>
<tr>
<td>[R1]</td>
<td>Minutes of meeting</td>
<td>MoM_TI_21062012.docx</td>
<td>1.0</td>
<td>2012-06-21</td>
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<td>[R2]</td>
<td>Minutes of meeting</td>
<td>MoM_TI_Concept Study_2013_07_18.docx</td>
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<td>2013-07-18</td>
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<td>[R3]</td>
<td>Review report</td>
<td>Concept_Study_TI_2014_03_10_draft.docx</td>
<td>3.0</td>
<td>2014-03-10</td>
</tr>
<tr>
<td>[R4]</td>
<td>Minutes of meeting</td>
<td>Workshop Kat 3 vs. HFT 61508 20130719.docx</td>
<td>1.0</td>
<td>2013-07-19</td>
</tr>
</tbody>
</table>

*Table 4: Documents from Testing Agency*
5 Result of the concept review

5.1 Approach of the concept study

For the evaluation of the safety architecture for equivalence related to category 3 of [N1] an example application was defined. The impact of faults on this safety function and the control of different fault scenarios according to [N1] and [N2] was analyzed with a Failure Mode and Effects Analysis (FMEA). Within this FMEA diagnostic measures and timing aspects have been regarded.

Result:

Based on [D1], [N3] and [R4] the following main criteria have been identified for reaching the equivalence of category 3 according to [N1]:

- The system and its components comply with a systematic capability (SC) ≥ 2 according to IEC 61508:2010 including measures to control and avoid systematic faults
- The safety function is performed in a high demand or continuous demand mode and has a defined safe state
- Faults are detected and the safe state is achieved within the process safety time
- An independent achievement of the safe state is ensured by a mandatory monitoring device
- An independent supervision of the execution of the on-chip safety mechanism is ensured
- An additional diagnostic ability like using information redundancy is provided by the application
- For each safety relevant element a combination of (minimum two) diagnostic measures has to be implemented. At least one of these diagnostic measures has to provide a diagnostic coverage of high. The following safety measures have been regarded in the concept study:
  - Information redundancy techniques supported by the application
  - Independent fault detection by the monitoring device
  - On-chip hardware implemented diagnostic measures with fault indication to the monitoring device
  - By software implemented diagnostic measures with fault indication to the monitoring device
- Measures against common cause failures covering the different devices
- Measures against common cause and cascading failures covering on-chip elements
- Limitation of usage up to performance level d
- Integration and verification has to be done according to the applied safety standards including functional safety management and lifecycle handling
The reaching of equivalence to category 3 according to [N1] has to be evaluated for each safety function separately.

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