Safety is becoming increasingly important in machine and plant construction. These high requirements mainly serve to protect human beings, but material assets and the environment are also receiving more consideration. The goal of functional safety is to minimize or at least reduce the risks that can occur during normal or impaired operation of machines or facilities. The first step of this is achieved with redundant systems. For example, axes that are moved in safety-oriented applications require redundant position information and dual-channel safety systems in order to perform the corresponding safety functions.

Various system configurations can be realized in order to capture independent position values. One possibility is using two encoders per axis, but due to cost considerations, a solution with only one position encoder is aspired to in most cases. HEIDENHAIN offers safety-related position encoders as a purely serial, single-encoder solution.

The dual-channel safety system of HEIDENHAIN controls is achieved by a dual-channel control architecture. The two computers are located in the MC main computer and CC controller unit components, where two independent software processes run. These two processes realize two safety channels, which capture and evaluate all safety-relevant signals in the two channels.

**Basic principle**

Controls and position encoders from HEIDENHAIN with functional safety meet safety integrity level 2 (SIL 2) as per the EN 61508 standard, as well as the performance level “d” as per ISO 13849-1 (which replaced ISO 954-1). These standards describe the assessment of safety-oriented systems, for example based on the failure probabilities of integrated components and subsystems. This modular approach helps manufacturers of safety-oriented systems to implement their systems, because they can begin with prequalified subsystems. Safety-related position encoders and the iTNC 530 with HSCI control accommodate this concept.
HEIDENHAIN is planning on offering controls with functional safety starting in the middle of 2008. Two redundant safety channels that work independently of each other are the foundation for controls with functional safety. All safety-relevant signals are captured, processed and output via two channels. Errors are detected by mutual comparison of the states and data in the two channels. This way, the occurrence of just one error in the control does not lead to the safety functions being incapacitated.

The first control available with functional safety will be the iTNC 530 with HSCI. The concept described here will also be used for other controls from HEIDENHAIN in the future.

The HEIDENHAIN control system with functional safety consists of the following subsystems:
- HEIDENHAIN control with functional safety
- HSCI system with MC 6xxx main computer and CC 6xxx controller unit
- PL 6000FS for connecting safety-relevant inputs and outputs
- MB 6xxFS machine operating panel
- TE 6xx keyboard unit
- BF 2xx visual display unit
- Power stages and drives for feed axes and spindles
- Inputs and outputs
- PL 6000 FS for connecting safety-relevant input/output systems and the MB 6xxFS machine operating panels. This means that all safety-relevant signals (e.g. permissive buttons, door contacts, emergency stop button) are captured in two channels, and are evaluated independently of each other by the MC and CC. The MC and CC use separate channels to address the power stages, and to stop the drives in case of an error.

### Safety-related operating modes

HEIDENHAIN controls with functional safety offer four safety-related operating modes as per the EN 12 417 standard (Machine Tools – Safety – Machining Centers). The application-oriented operation offered by this promises a high level of acceptance, and therefore safety.

The goal is to make actions by the machine operator at machining centers possible during automated production runs, even when protective measures are not in effect (such as protective doors being open), without danger to the operator:
- **Setup**
- **Manual intervention**
- **Process monitoring**

The following safety-related operating modes, as per EN 12417, can be selected, for example by a keylock switch:

**Operating mode 1: Automated or production mode**
- Operation only with closed protective door
- No machine motion possible if protective door is open

**Operating mode 2: Set-up mode**
- Operation with open protective doors
- Axis motions of 2 m/min at most
- Spindle stop within 2 revolutions
- Only one axis can be moved at a time (no interpolating motions)
- Permissive button must be pressed for axis motions

**Operating mode 3: Manual intervention**
- Operation with open protective doors
- Axis motions of 5 m/min at most
- Spindle stop within 5 revolutions
- More than one axis can be moved at a time (interpolating motions)
- Permissive button must be pressed for axis motions

**Operating mode 4: Advanced manual intervention, process monitoring**
- Operation with open protective doors
- Axis motions of 5 m/min at most
- Spindle stop within 5 revolutions
- More than one axis can be moved at a time (interpolating motions)
- Permissive button must only be pressed to start a motion

The basic safety functions are defined in the SKERN software, and cannot be changed. The SKERN tasks include:
- Triggering and monitoring stop reactions
- Monitoring of the safe limited speeds in the various safety-related operating modes
- Cross-comparing the data and states of the two safety channels
- Monitoring of system conditions, such as supply voltages, operating temperatures, etc.
The control requires reliable position information for numerous safety functions, including safe reduced velocity, safe absolute position, safe controlled stop, etc. Redundant information is required for this. Diverse techniques sometimes come into use for generating redundant position values. Genuine dual-channel redundancy can be ensured by installing two encoders per axis. Economy, however, makes a solution requiring only one position encoder preferable.

The trend toward purely digital drive concepts will require single-encoder solutions, which permit redundant position value acquisition through purely serial transmission, for safety-oriented applications.

HEIDENHAIN offers a solution with its safety-related position measuring systems. Single encoder solutions for safety-oriented applications according to IEC 61508 and EN 13849 are supported based on the purely serial EnDat 2.2 interface. All the benefits of serial data transmission are now also available in safety-related applications.

### Safety-related position encoders with purely serial data transmission via EnDat 2.2

In a safe drive, the safety-related position measuring system is a subsystem consisting of:
- Encoder with EnDat-2.2 transmission component
- Data transfer line with EnDat-2.2 communication and cable
- EnDat-2.2 receiver component with monitoring function (EnDat master)

### Integration of the position measuring system

The position measuring system is integrated via a physical and an electrical interface into the complete system. The encoder is mechanically coupled to the drive through the shaft connection and the coupling, both of which are determined by the geometry of the encoder. Including the EnDat master with monitoring functions in the safe control ensures its electrical integration. The necessary measures have already been defined. The control manufacturer must only implement them. And so the safety-related position measuring system can be incorporated as a subsystem with the corresponding failure probabilities into the safety-related evaluation of the plant’s or drive manufacturer’s total system.

### Function

The safety system of the position encoder is based on two mutually independent position values and additional error bits produced in the encoder and transmitted over the EnDat 2.2 protocol to the EnDat master. The EnDat master assumes various monitoring functions with which errors in the encoder and during transmission can be revealed. The two position values are then compared. The EnDat master then provides the two position values and mutually independent error bits to the safe control over two processor interfaces. In addition, the control monitors the functionality of the safety-related position measuring system and the EnDat master through periodically released tests (forced dynamic sampling).

The architecture of the EnDat 2.2 protocol makes it possible to conduct all safety-related information or control mechanisms during unconstrained controller operation. This is possible because the safety-relevant information is saved in the additional information. With every sampling cycle this additional information can be requested by the control in addition to the actual position. The architecture of the position measuring system according to IEC 61508 is regarded as a single-channel tested system.
A control from HEIDENHAIN with functional safety has two redundant safety channels that work independently of each other. All safety-relevant signals are captured, processed and output via two channels.

The “safe” control from HEIDENHAIN is based on the iTNC 530 HSCI. It makes purely digital processing of information possible, from the position encoder to the current controller.

The encoders from HEIDENHAIN for safety-related position measuring systems operate with purely serial data transfer. The two position values are already formed independently of each other in the encoder, and are transmitted to the safe control via the universal EnDat interface. The amount of wiring is minimized, and expensive connection cables become a thing of the past.

At this time, two absolute rotary encoders are available (in both singletum and multitum versions) as “safe” position encoders. Further absolute linear and angle encoders are in preparation.

### Control systems

<table>
<thead>
<tr>
<th>Control system</th>
<th>Version</th>
<th>Axes</th>
<th>Special feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>iTNC 530 HSCI</td>
<td>Contouring control for milling machines and machining centers</td>
<td>Max. 14 controlled axes and 2 spindles</td>
<td>Uniformly digital control concept with HSCI interface and EnDat-2.2 interface</td>
</tr>
</tbody>
</table>

### Rotary encoders

<table>
<thead>
<tr>
<th>Encoder</th>
<th>Version</th>
<th>Position values per rev</th>
<th>Revolutions</th>
<th>PFH</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECN 425</td>
<td>For mounting on motors and machines; Protection IP 64</td>
<td>33 554 432 (25 bits)</td>
<td>–</td>
<td>≤ 1 x 10^-8</td>
</tr>
<tr>
<td>EQN 437</td>
<td>Protection IP 40</td>
<td>33 554 432 (25 bits)</td>
<td>4 096 (12 bits)</td>
<td>≤ 1 x 10^-8</td>
</tr>
<tr>
<td>ECN 1325</td>
<td>For integration in motors; Protection IP 40</td>
<td>33 554 432 (25 bits)</td>
<td>–</td>
<td>≤ 1 x 10^-8</td>
</tr>
<tr>
<td>EQN 1337</td>
<td></td>
<td>33 554 432 (25 bits)</td>
<td>4 096 (12 bits)</td>
<td>≤ 1 x 10^-8</td>
</tr>
</tbody>
</table>

### Angle encoders

<table>
<thead>
<tr>
<th>Encoder</th>
<th>Version</th>
<th>Hollow shaft</th>
<th>Position values per rev</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCN 2xx</td>
<td>With integral bearing and integrated stator coupling</td>
<td>Ø 20 mm</td>
<td>67 108 864 (26 bits)</td>
<td>± 5”</td>
</tr>
<tr>
<td>RCN 7xx</td>
<td></td>
<td>Ø 60 mm / Ø 100 mm</td>
<td>53 687 0912 (29 bits)</td>
<td>± 2”</td>
</tr>
</tbody>
</table>

### Linear encoders

<table>
<thead>
<tr>
<th>Encoder</th>
<th>Version</th>
<th>Scale housing</th>
<th>Measuring length</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC 185</td>
<td>Sealed, with scanning carriage with integral bearing</td>
<td>Full size</td>
<td>To 4 240 mm</td>
<td>± 5 µm / ± 3 µm</td>
</tr>
<tr>
<td>LC 485</td>
<td></td>
<td>Slimline</td>
<td>To 1 240 mm</td>
<td>± 5 µm / ± 3 µm</td>
</tr>
</tbody>
</table>

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1) Availability: planned for middle of 2008
2) Encoders are in preparation; exact designations and versions have not been defined yet
3) Availability: planned for end of 2008
4) Probability of dangerous failure per hour

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For further information

- Product Information
  ECN 1325 / EQN 1337

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