ME @ Bosch Rexroth

Mobile Electronics – Open, connected, scalable
With BODAS into the digital future
Now. Next. Beyond. Just to name a few challenges…

- Preventive Diagnosis
- IoT
- Functional Safety
- Connected Construction Sites
- Automated Operation
- Connected Agriculture
- Self-driving machines
- Regulations for environmental protection
- Electrification Powertrain / Implement
- Cyber Security
- Modular Electronic Control Units
- Cloud-based Development
- Automation & Robotics
- Zero emissions
- Agricultural land per head by 2050: - 35%
- Electrification
ME @ Bosch Rexroth - Organization
Mobile Electronics – Our Business: Managing diversity!

Automotive

Mobile Hydraulics

Our customers

Our projects

Serving small to large OEM in a wide range of applications!
### Axial piston units
- High-pressure units up to 450 bar nominal pressure and 500 bar max. pressure
- Displacement volumes from 5 cm³ to 1,000 cm³
- New: A24 BR10, A1VO BR10, A4VTG BR34, A41CTU

### Mobile controls
- Function optimizing of the control components as well as in application-specific solutions.
- Precise, efficient control of travel and implement hydraulics
- Electro hydraulic systems for more operating comfort and safety
- Design-to-Region

### Mobile electronics
- Homburg
- Elchingen
- Schwieberdingen

### Service Mobile Hydraulics
- Elchingen
- Horb
- Nuremberg
- Homburg
- Vénissieux
- Fountain Inn
- Tsuchiura
- Beijing

### Casting
- Hydraulic, chilled and continuous casting, flashing, grinding, and lapping disks for ball pivot manufacturing
- Cores, accurate to size, suitable for complex internal contours
- Rapid tooling/rapid prototyping using direct cronning
BODAS – Bosch Rexroth Design and Application System:
Extensive and modular mobile electronics product range with high-quality hardware components, standard application software packages, diagnosis and programming tools

- Realization of products and applications complying functional safety requirements
- High product quality and long-term availability
- Proven Bosch technology for mobile working machines
- Development competence and system know-how for mobile applications
ME @ Bosch Rexroth - Organization
Development & Product Management

Schwieberdingen (Germany)

Elchingen (Germany)

Development HW
Controllers

Development Basic-SW & Tools
BIOS, Runtime-Systems, Tools

Development Machinery Functions
Application Software
Platform Software

Product Management
Mobile Electronics
ME @ Bosch Rexroth - Organization
Requirements, Innovation and Engineering

Innovation
Mobile Applications
- Innovations
- Trends
- Studies

ECU / Sensor Technologies

Engineering
Mobile-specific
- Requirements Management
- Functional Design
- Tests & Validations

Quality assurance

PCB layout & optimization

Manufacturing
Stock, Shipping, Billing, …

Manufacturing processes, functions, plants

→ Keeping focus on requirements / design for mobile applications
→ Taking profit of Bosch competence, technology and production

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Synergies through the association with BOSCH

Example: Assembled products @ Bosch

**BODAS Controllers**
- Parts shared with BOSCH controllers: housings, connectors, qualified electronics parts, integrated circuits
- BOSCH know-how utilized in development and qualification
- Production at Bosch plants
- Automotive quality standards
- BOSCH base software

**Automotive Sensors for Mobile Machines**
- Automotive BOSCH sensor technology
- Integrated diagnosis
- Provision of automotive communication techniques for reduction of machine complexity
- Automotive quality standards
- Used in mass production quantities in the automotive sector – e.g. within ABS systems
ME @ Bosch Rexroth – BODAS Controllers
Engineering principles RC Product Family

Scalable
BODAS RC family from small to large controllers

Open
BODAS RC family with API/BSW open to be programmed

Easy Access
BODAS RC family provides standard protocols for diagnosis

Application Software architecture designed to support adaptations
ME @ Bosch Rexroth – BODAS Controllers
BODAS Controller Portfolio present and future

- RC4-5/30
- RC10-10/31
- RC5-6/40 SOP 2018/19
- RC/40 – mid In development
- RC/40 – large In development
- RC12-10/30
- RC20-10/30
- RC28-14/30
- pin compatible
ME @ Bosch Rexroth – BODAS Controller
Bosch Rexroth controller – Overview

**RC28-14/30 * RC20-10/30 * RC12-10/30**
- SOP 2011 / 2012
- Scalable RC-family with identical pinning
- Variants differentiate in number of outputs only
- Programmable in C und BODAS-design
- Usable for safety functions in accordance with EN ISO 13849 up to PL d or ISO 25119 up to AgPL c

**RC4-5/30**
- SOP 2013
- Programmable only in C
- Standard Software
  - AFC30 available
  - VAC, SPC, LLC in development

**RC10-10/31**
- SOP 2016
- Proportional outputs (PWM): 4x HS, 6x LS
- Switch outputs: 10x HS
- Programmable in C und BODAS-design
- Usable for safety functions in accordance with EN ISO 13849 up to PL d or ISO 25119 up to AgPL c
- New features / highlights:
  - 270 MHz processor
  - Active reverse polarity protection
  - CAN wake-up
  - SAE J2716 SENT digital sensor interface
  - CAN interface with active ISOBUS termination
  - LIN interface
  - Increased current rating for outputs: 3 A / 4 A
  - Separate inhibit inputs for two main switches
ME @ Bosch Rexroth – BODAS Controllers

BODAS Controller Portfolio present and future

RC4-5/30

RC10-10/31

RC5-6/40

RC5-6/40 SOP 2018/19

RC/40 – mid
In development

RC/40 – large
In development

RC12-10/30
RC20-10/30
RC28-14/30

pin compatible
ME @ Bosch Rexroth – BODAS Controllers
Outlook series 40 – overview HW

New generation of BODAS control units

- Rugged design for use in mobile machinery
- Scalable platform with three pin-compatible control units (small, mid, large)
- Latest Bosch technology in circuitry, base software, mechanics and manufacturing
- Usable for applications with functional safety requirements
- Part of Bosch E&E architecture for off-road and commercial vehicles

Enhanced Functionality

- Multi-Core μC with lockstep functionality
- Hardware Security Module (HSM) integrated
- Multi-functional inputs for compatibility with many sensors and input devices
- Power outputs with enhanced diagnostics features and high currents
- Outputs for low power consumers, e.g. relays
- Communication interfaces: CAN FD and others

Freely programmable for a variety of hydraulics applications
Functional safety acc. EN ISO 13849 up to PL d and ISO 25119 up to AgPL d (SRL2)
ME @ Bosch Rexroth – BODAS Controllers
Outlook series 40 – overview SW

**New generation of BODAS control unit Base SW**

- Base Software supplied by Rexroth based on Bosch automotive technology
- Programming of application software (ASW):
  - In a high level language C or Matlab
  - CODESYS 3.5
  - Access to application Rexroth modules ASlib/ASopen
  - MASAR compliant templates and modules for optimized and efficient SW engineering

**Web Based configuration “cloud”**

- A modern user friendly front-end tool with import functions
  - → simplified configuration
- Consistency and plausibility check before compilation
  - → increased quality
- Automatic processes incl. versioning managements
  - → always up-to date!
- Ready-to-run base software
  - → more time for ASW development

**New and modern web based tooling with highest degree of quality, safety and multi functionality**
BODAS RC comparison RC30 <> 40

**Series 3x Takeovers**
- Bosch technology
- Bosch manufacturing
- EPA housing
- Connector type (fits MA8)
- EN ISO 13849 up to PLd
- SENT sensor interfaces
- C and BODAS-design

**Series 3x improved**
- Configurability of inputs
- ISO 25119 now up to Ag PL d
- High output currents
- Current control accuracy
- Output diagnosis
- ISOBUS implementation
- CCP replaced by XCP (eXtended calibration protocol)

**Series 40 new**
- Multi-Core and Lockstep μC
- Relay outputs 200 mA
- CAN FD
- Safety certification
- Easy config tool
- Cyber Security ready (HSM)
**Programming Tool**

- Programming of application software independent from Rexroth
- Fast realization of applications by usage of B-d RC/30 templates and AS-libraries

**Characteristics**

- Used for programming BODAS RC controllers in IEC 61131-3 languages
- B-d is based on CODESYS 2.3 with integrated development suite with editor, debugger and compiler extended with high value and mighty BODAS API commands (see C-API)
- Simple and proven interface for application software through Rexroth know-how
- Available as download (free of charge): [Link](#)
- Fast development by use of library functions
- Support of diagnostic functions via BODAS-service
- CANopen library available
ME @ Bosch Rexroth – Tools
BODAS-service

Service Tool

- Available versions (SW available as download: Link)
  - Demo (only visualization free of charge)
  - Diagnosis
  - Flash
- Full Version Licensing via USB hard lock, optional with company SW licensing

Characteristics

- User-friendly PC service tool for use with BODAS RC-controllers via CAN
- Functionalities
  - Flashing of applications (*.hex) onto BODAS products
  - Parameter “EPR” file reading and writing
  - Adjustment of parameters
  - Visualization of process values and error codes
  - Creation of project specific diagnostic views “guided commissioning” (new!)
  - IoT wireless diagnosis with BODAS Telemetric partners integrated (new!)
  - EPR comparison and merging Tool for easiest variant handling (new!)
  - Parameter caching for faster connection (new!)
ME @ Bosch Rexroth – Tools

C-API

Characteristics

- Hardware abstraction layer used for easy programming of BODAS RC-controllers in high language C
- Open Core SW engineering with following support:
  - Configuration and control of inputs and outputs
  - Task management and System core function control
  - Support of safety relevant functions corresponding to EN ISO 13849 / ISO 25119
  - Support of communication interfaces (incl. CANopen, J1939, CCP, UDS)
  - Extensive system-/self-diagnostics
  - Support of diagnostic functions via BODAS-service
  - Usable with model-based software development
  - CCP Diagnosis support integrated

Programming Interface

- Programming of application software independent from Rexroth in C language
- Programming in C language without detailed knowledge of the μC / BODAS RC hardware
- Requires third party C compiler, e.g. RC/30 HighTec GNU

Data sheet RD/RE 95086
Customer loader API

Programming Interface
- Used to support development of customer specific flashing logics / customer flash tool interfaces
- Available for series 30 controllers
- Requires third party C compiler, e.g. RC/30 HighTec GNU

Characteristics
- Customer specific adaptation Rexroth RC bootblock
- Given function set based on Rexroth C-API
  - Basic system functions
  - Specific digital inputs reading (finger print service)
  - CAN communication
  - Flash programming
  - Asynchronous communication
  - EEPROM (read/write)

Data sheet RD/RE 95086
ME @ Bosch Rexroth – Tools
Outlook RC/40 – open core configuration

Configure RC:
- I/O
- CAN, etc
- Memory
- OS

OEM with web front-end

Configure RC:
- I/O
- CAN, etc
- Memory
- OS

Configure RC: SW-HW-Spec

Generate Algorithm

Easy Config

*cfg.h
*cfg.c

CUBAS

Build Process

BODAS-BSW

Download

Offline ASW Development based on configured BSW

Compile

*.hex

Flash

Update ASW (CR/TR)

Download

OS-Cfg,
Diag-Cfg

FSP

Update RC configuration (e.g. harness, CAN)

Machine Setup Change Request

BODAS-BSW

**.hex**

*cfg.h
*cfg.c

SW validation

Update ASW (CR/TR)

Download

Offline ASW Development based on configured BSW

Compile

*.hex

Flash

Update ASW (CR/TR)

Download

Offline ASW Development based on configured BSW

Compile

*.hex

Flash

Update ASW (CR/TR)

Download

Offline ASW Development based on configured BSW

Compile

*.hex

Flash

Update ASW (CR/TR)
## ME @ Bosch Rexroth – Tools
### Outlook RC/40 Tools – Key benefits

<table>
<thead>
<tr>
<th>Features</th>
<th>Key benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Software supplied by Rexroth based on Bosch technology</td>
<td></td>
</tr>
<tr>
<td>RC configuration via Cloud tool:</td>
<td>simplified configuration</td>
</tr>
<tr>
<td>- A front-end tool with import functions</td>
<td>increased quality</td>
</tr>
<tr>
<td>- Consistency and plausibility check before compilation</td>
<td>always up-to date!</td>
</tr>
<tr>
<td>- Automatic processes incl. versioning managements</td>
<td>more time for ASW development</td>
</tr>
<tr>
<td>- Ready-to-run base software</td>
<td></td>
</tr>
<tr>
<td>Programming of application software (ASW):</td>
<td>integration of available modules possible</td>
</tr>
<tr>
<td>- Still as in RC/30 in a high level language C or Matlab</td>
<td></td>
</tr>
<tr>
<td>- Access to Rexroth modules</td>
<td></td>
</tr>
<tr>
<td>- Many AddOn Features in the Cloud</td>
<td></td>
</tr>
</tbody>
</table>
Easy Config

- Os-Cfg, Diag-Cfg
- NvRam-Cfg
- Can-Cfg
- Hw-Cfg

**Characteristics**

- A front-end tool in Bosch Feature Store Platform (FSP) for the SW-developers (OEMs, Rexroth)

- Configures the RC online
  - Pins for sensors and actuators
  - CAN-Bus manually or via a dbc-import
  - OS, timers/tasks, diagnosis
  - Memory – for parameters and diagnosis
ME @ Bosch Rexroth – Tools
Outlook RC/40 – Feature Store Platform (FSP)

Characteristics

- A web-based service from Bosch
- manages the complete toolchain (back-end) incl. workflow
- encapsulates AUTOSAR, low-level requirements and runs the compiler
- administrates users, projects and toolchain versions
- delivers the downloadables:
  - BODAS-BSW (incl. SW-objects, interface-files)
  - Documentation, ...
Sensors
ME @ Bosch Rexroth – Sensors

Sensor overview

- Speed
  - DSM
  - DSA
  - HDD
- Position
  - PO1
- Angle
  - WS1
  - AN2
  - AN3
- Inertia
  - MM5.10-EOL
- Pressure
  - PR3
  - MM7.10
  - PR4
- Force
  - KMB
- Temperature
  - TS Fluid
- Contamination
  - VS
Inertial sensors

- Supply voltage range: 7 ... 16V
- All signals provided by CAN (CAN 2.0 B - ISO 11898)
- Operating temperature: -40 ... +85°C; Protection class: IP6K7
- Small and compact size with Standard 4-pin TYCO connector
- Configurable settings
  - Baud rate (125 / 250 / 500 / 1000 kBaud)
  - CAN Identifier length (11 / 29 bit) and CAN update rate: 5, 10, 20 ms
  - CAN ID’s and Low pass filter settings: 15, 30, 60 Hz
- Measures following inertial signals (5D)
  - Longitudinal acceleration aX
  - Lateral acceleration aY
  - Vertical acceleration aZ
  - Roll rate \( \Omega_X \), Yaw rate \( \Omega_Z \), Pitch rate \( \Omega_y \) (MM7.10)
- Bosch Automotive Quality
ME @ Bosch Rexroth – Sensors
Pressure sensor PR4

Technical Specification

- Stainless steel sensing element with metal thin film strain gages
- Pressure ranges: 50, 280, 420, 600 bar
- Sensor supply: 5V ± 0.25V
- Sensor signals:
  - Ratiometric 0,5V...4,5 V @ 5V supply
  - **SENT according SAE J 2716**: Diagnosis + high accuracy and resolution + robustness against EMC and other disturbances
- Operating temperature: -40... +140°C
- Protection class: IP67 and IP69K
- Connector: Bosch Compact 1.1
- To be mounted with a socket wrench
- Tightening torque: up to 45 Nm
Pressure sensor PR4 – SENT interface comparison

### Signal chain analog

1. High pressure sensor PR4
2. ASIC-circuit, EMC measures
3. Measuring bridge
4. ADC (Analogue-Digital converter)
5. Signal processing
6. DAC (Digital-Analog converter)
7. Connector
8. Mating connector
9. Wiring harness
10. Mating connector
11. Controller
12. Analog filtering
13. Signal processing
14. ADC (Analogue-Digital converter)
15. Digital signal processing

### Signal chain digital

1. High pressure sensor PR4
2. ASIC-circuit, EMC measures
3. Measuring bridge
4. ADC (Analogue-Digital converter)
5. Digital signal processing
6. Connector
7. Mating connector
8. Wiring harness
9. Mating connector
10. Controller
11. EMC circuit
12. Digital signal processing
13. Transmission without tolerances/ signal disturbances

**Example**

(600 bar, @pmean, 150°)

- Avoidance of digital-analogue conversion: **improvement 0.1%**
- Sensor accuracy loss: within proper temp. range: **+0.6 bar**
- Conversion from analogue to digital in controller → signal conditioning + 13 bar (w/ standard mobile components)
  → With SENT improvement of **+14 bar**
Application Software
Standard Application Software AS – Overview

Extensive range of solutions available

DRIVE
- eDA
- DRC
- DPC

WORK
- VAC
- EHC
- TVC

AUXILIARY
- SPC
- LLC
- KPC
- AFC
ME @ Bosch Rexroth – Application Software
Standard Application Software AS – Product lines

ASrun

Plug & Run your machine!
- Off-the-shelf available
- No SW-development required
- For customers who are happy with the predefined scope

Description
- Executable code generated out of ASopen
- Delivery on RC
- Customizable via BODAS-service

ASopen

Open for modifications
- Solid base for efficient customer specific extensions
- Modular, well tested & documented

For Each Application the Right Software

Available on component-level
- Rexroth-expertise bundled in SW
- Re-use across various applications
- Well tested & documented

- Collection of SW components with well-defined tasks
- Software components composed into packages
- For customers who create own software

ASlibrary

Collection of SW components with well-defined tasks
- Software components composed into packages
- For customers who create own software
ME @ Bosch Rexroth – Application Software

BODAS-drive – Overview

- **DRC**
  Comprehensive drive control solution covering various drivetrain configurations including gearbox management

- **eDA**
  Full electronic control for basic hydrostatic drive

Both available as
- ASrun Plug & Run your machine!
- ASOpen Open for modifications
- ASlibrary Available on component level

NEW: eDA – the perfect entry-level drive control solution
BODAS-drive eDA – Basic travel drive control

**Characteristics**
- Capable for systems with variable pumps in combination with constant or variable motors
- Optimized for operation with new pump generation A4VG series 35
- Support of various engine types - mechanical and electronic control
- Functional safety according to EN ISO 13849
- Software offers features for automotive driving as well as functions for safety, comfort and energy efficiency:
  - Creep Mode
  - Load limiting
  - Component protection
  - Different driving modes – up to 3
- ECO mode – Fuel saving up to 20 %
- Modular software concept for efficient realization of customer-specific extensions

**Highlights**
- Control software for hydrostatic drivetrains of wheeled loaders, tele handlers, forklift trucks and comparable applications
- Running on dedicated eDA-controller
- Easy application and commissioning

Data sheet RD/RE in work
### eDA PREMIUM

<table>
<thead>
<tr>
<th>Safety Functions</th>
<th>Features DA</th>
<th>Features DA+</th>
<th>CAN engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe Standstill</td>
<td>Automotive Driving</td>
<td>Velocity Limit Switch (Turtle)</td>
<td>Electronic Drive Pedal</td>
</tr>
<tr>
<td>Safe Drive Direction</td>
<td>Pump Control, DA emulation incl. anti-stall</td>
<td>Velocity Control (Creep)</td>
<td>Engine Speed Control</td>
</tr>
<tr>
<td>Safe Reversing</td>
<td>Motor Control, DA emulation</td>
<td>Up to 3 Drive Modes</td>
<td>Engine Overspeed Protection</td>
</tr>
<tr>
<td>Safe Deceleration</td>
<td>Reversing</td>
<td>Diagnostics</td>
<td>Load Limiting Control</td>
</tr>
<tr>
<td>Safe Acceleration Limit</td>
<td>Inching</td>
<td>Limp Home Mode</td>
<td>DHC ECOdrive</td>
</tr>
<tr>
<td>Safe Deceleration Limit</td>
<td>Electronic Pressure Cut-off</td>
<td>Basic ECOdrive</td>
<td>Electronic Hand Throttle</td>
</tr>
</tbody>
</table>

Component Calibration
BODAS-drive DRC – Travel drive control

Characteristics

- Capable for systems with variable pumps in combination with constant or variable motors
- Covering a wide range of hydrostatic drivetrain and gearbox variants of wheeled mobile machines
- Software developed according to the standards EN ISO 13849 (up to PLd) and ISO 25119 (up to AgPLc)
- Software offers features for automotive driving and transmission control as well as functions for safety, comfort and energy efficiency:
  - Velocity limitation, Load limiting
  - Component protection e.g. speed, temperature
  - Different driving modes – up to 5
- ECO mode – Fuel saving up to 20 %
- Modular software concept for efficient realization of customer specific extensions

 Highlights

- Software solution embedded in Rexroth controller RC12-10/30 to control hydrostatic travel drives of wheeled loaders, tele handlers, forklift trucks and comparable applications
- Sophisticated bundle of functions including gearbox control
# ME @ Bosch Rexroth – Application Software

## BODAS-drive DRCA42 - Function overview

<table>
<thead>
<tr>
<th>Drive Functions</th>
<th>Comfort Functions</th>
<th>Energy efficiency and component protection</th>
<th>Safety Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive Driving</td>
<td>Velocity Limitation</td>
<td>DHC ECOdrive*</td>
<td>Safe Standstill</td>
</tr>
<tr>
<td>Pump Control</td>
<td>Cruise Control*</td>
<td>DHC ECOwork*</td>
<td>Safe Reversing</td>
</tr>
<tr>
<td>Motor Control</td>
<td>Tractive Effort Limitation*</td>
<td>Engine Overspeed Protect.*</td>
<td>Safe Drive Direction</td>
</tr>
<tr>
<td>Proportional Driving</td>
<td>Hand Throttle*</td>
<td>Load Limiting Control Drive</td>
<td>Safe Speed Limitation</td>
</tr>
<tr>
<td>Engine Speed Control</td>
<td>Up to 3 Drive Modes</td>
<td>Temperature Range Protect.</td>
<td>Safe Deceleration</td>
</tr>
<tr>
<td>Reversing</td>
<td>Up to 5 Drive Modes*</td>
<td>Power Limitation</td>
<td>Safe Acceleration Limit</td>
</tr>
<tr>
<td>Inching</td>
<td>Brake Lamp Control*</td>
<td></td>
<td>Safe Deceleration Limit</td>
</tr>
<tr>
<td>Service Brake Influence*</td>
<td>Parking Brake Control*</td>
<td></td>
<td>Safe Parking Brake</td>
</tr>
<tr>
<td>Gearbox Shift in Standstill*</td>
<td>Diagnostics &amp; Fault Lamp</td>
<td></td>
<td>Safe Brake Light</td>
</tr>
<tr>
<td>Gearbox Shift-on-Fly*</td>
<td>Limp Home Mode</td>
<td></td>
<td>Safe Operator Detection</td>
</tr>
<tr>
<td>Gearbox Sum. 2+1*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shift radial piston motors*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Classification of functions in Basic und Premium*!

- Unified Diagnostic Services (UDS)
- Autocalibration for pump & motors
Functional Safety
Functional Safety
Definition of terms

What is functional safety?

- **Functional Safety** = **FuSa** = **FuSi** (in German)
- **Functional Safety** = absence of unreasonable risk due to hazards caused by malfunctioning behavior of systems
- **Safety function** = function of a machine whose failure can result in an immediate increase of the risk(s)

Why is functional safety needed?

- Complexity of functionalities increases with E/E/PES
- Behavior of the system can hardly be defined
- Potential hazards are hidden within the complex system
- Risk reduction for machinery is required by **legislation** in EU states, based on Machinery Directive 2006/42/EC

⇒ Systematic approach necessary! Functional safety to be considered to be machinery directive conform
What is Safety (vs. Security)?

SECURITY
protects machines from humans (attackers)

SAFETY
protects humans from machines

A security attack can lead to safety issues
Functional Safety
BODAS goes - Cyber Security

Layer 1: Individual ECU
- Protect integrity of ECU SW & data
- Hardware Security Module (HSM)

Layer 2: In-vehicle network
- Protect integrity of critical in-vehicle signals

Layer 3: E/E-Architecture
- Protect and separate domains by E/E architectures and gateways

Layer 4: Connected vehicle
- Vehicle firewalls and security standards for communication and external interfaces

BODAS series 40
HW/SW support

BOSCH Technology
Know How and solutions
What is a Safety Function (vs. Functional Safety)?

**Safety Function**
- Gives in Case of Emergency a control option to reach a safe state

**Functional Safety**
- Secures the probability that the safety functions work according to expectation

A Safety Function without consideration of FuSa may lead to higher safety issues.
Functional Safety
Legal Responsibility

Extract from attachment 1 from the machinery guideline 2006/42/EC:

“The manufacturer of machinery or his authorized representative must ensure that a risk assessment is carried out in order to determine the health and safety requirements which apply to the machinery. The machinery must then be designed and constructed taking into account the results of the risk assessment.”

Additional information regarding EU machinery directive: http://eur-lex.europa.eu

→ It is not defined, that a OEM has to follow any safety standard, except that they are defined within a machine or application specific standard, according to the machinery guideline!

Advantage when using harmonized standard:

When a harmonized standard such as DIN EN ISO 13849 for machine safety is used and confirmed, the assumption is, that thus also the functional safety requirements by law according to the machine guideline are confirmed!
Everybody is responsible: Observance of relevant processes, quality management, consistent risk management, obligation to inform, proper documentation and marketing...
Functional Safety

Safety Standards – Reversing Burden of Proof

Legal obligation to comply with Machinery directive protection goals, not with harmonized standards. But:

- compliance with harmonized standard
  - presumption of conformity: legally presumed proof of conformity
  - burden of proof at court, prosecutor, plaintiff

- non-compliance with harmonized standard
  - no presumption of conformity despite compliance with the protection goals of the directive
  - burden of proof at machine manufacturer

Source: Rexroth internal Product Safety Workshop, Hydrive Engineering
10 steps to performance level

1. Risk assessment and reduction
2. Identification of Safety Functions
3. Specification of the required PLr
4. Choice of System Architecture
5. Modeling the System with Block Diagrams
6. Failure and Diagnose
7. Determination of PL
8. Evaluation of System Robustness
9. Software Requirements
10. Verification and Validation

Safety concerns all parts

Following EN ISO 13849, each component is only one chain link in the safety chain!

If one fails the others have to detect this failure and bring the machine into a safe state!

A single component certification would not fulfill system safety requirements!
Summary – Machine manufacturer and suppliers

**Responsibility of Machine manufacturer**
- Risk assessment: Determine risk, define measures
- Design and manufacture safe machinery: no hazard for persons and environment
- Create requirements to suppliers of components and sub systems
- Instruct users and monitor the actual use of the product
- Declare conformity to machinery directive: CE mark and related documentation

**Responsibility of Supplier**
- Support the machine manufacturer with suitable products, fulfill his requirements
- For special cases “incomplete machinery” and “safety component”:
  - Fulfill requirements from machinery directive
- Provide information for integration and for validation
  - technical data like MTTFd and DC for components and sub systems
Thank you!!