BiSS
SAFETY

Concept

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OVERVIEW

BiSS Interface
BiSS (**Bi**directional/**S**erial/**S**ynchronous) is a digital, serial interface protocol for fast and safe isochronous process data transmission, particularly used in motor feedback systems. Simultaneous to the reception of sensor process data and the transmission of actuator process data in real-time, the BiSS protocol is capable of register data transfers without interrupting the process data stream.

BiSS Safety
BiSS Safety is a profile definition for *BiSS* that has been certified by TÜV Rheinland for safety-critical applications up to SIL3 according to IEC61508:2010. *BiSS Safety* uses the concept of a "Black Channel" transmission and specifies the data channel contents in order to ensure failure mode detection as defined in IEC61784-3 using redundant position words, different CRC polynomials and a sign-of-life counter. *BiSS Safety* is fully compatible with *BiSS* and all of its features including line delay compensation, processing times and daisy-chaining of additional sensors.

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SYSTEM STRUCTURE

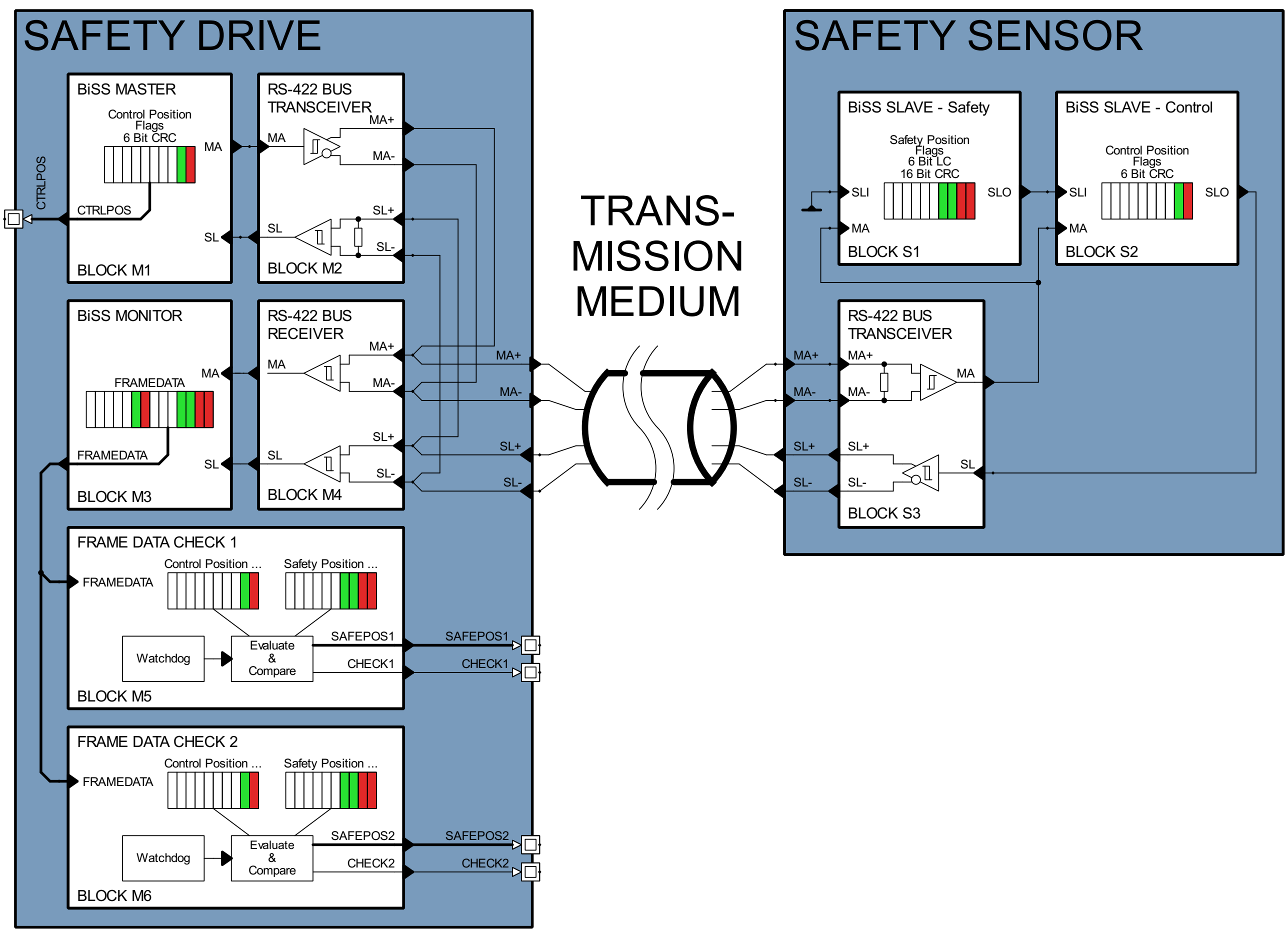

Figure 1: Example of a *BiSS Safety* system

SYSTEM DESCRIPTION

Figure 1 shows a typical setup of a *BiSS Safety* system with a safety drive and a safety sensor.

Safety Sensor
Two independent position words are generated by two daisy-chained sensors. One sensor generates the control position word (CPW) and the other sensor generates the safety position word (SPW). CPW and SPW are sent over a single cable from the safety sensor device on the right to the safety drive on the left.

Safety Drive
The safety drive contains the standard *BiSS Master*, a *BiSS Monitor* and two instances for *Frame Data Checks* (e.g. safe MCUs). The *BiSS Master* initiates the *BiSS* communication. The *BiSS Monitor* observes the *BiSS* transmission and provides the data channel contents to the *Frame Data Check*. Additionally, the monitor can provide safety functions and features to support a safe operation, e.g. it may check validity of the BiSS frame and indicate errors in case of issues. Both data channels are evaluated by the redundant *Frame Data Check* units. Each of them checks the data integrity by verifying CRC values, comparison of the position words and evaluation of the sign-of-life counter in order to detect possible transmission failures. The *Frame Data Check* instances signal their results and the safe position value to the superordinated control for further processing and actions.

DATA CHANNELS

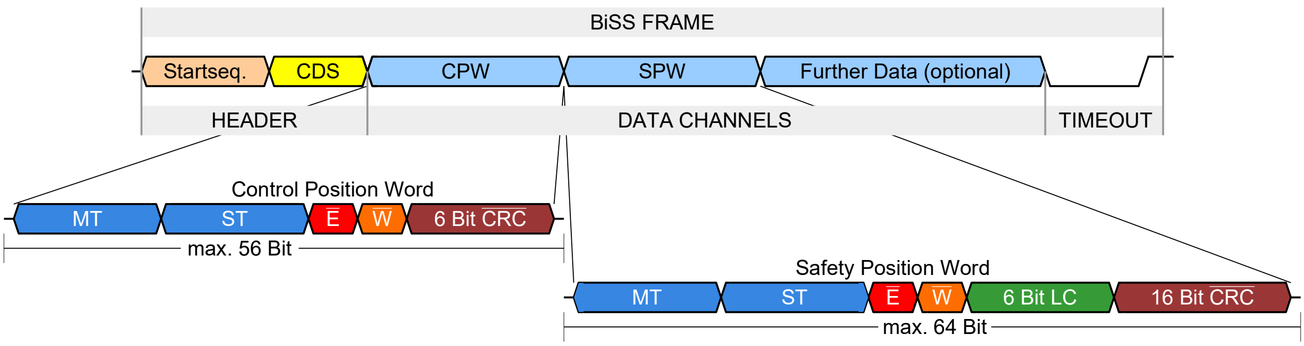

Figure 2: Data channel contents according to the *BiSS Safety* profile

In a typical *BiSS Safety* application two independent rotary position words are generated. Each position word is generated by one sensor and transmitted in a separate data channel along with additional data for failure mode detection.

Control Position Word (CPW)
Usually, the CPW is a high resolution position word and used for motor feedback. As shown in Figure 2, the CPW may contain multiturn information (MT), which is the number of full mechanical revolutions, and singleturn information (ST), which is the angle information within one mechanical revolution. Validity of the position can be indicated to the BiSS master with an error ($\overline{E}$) and a warning bit ($\overline{W}$). Position, error bit and warning bit are protected against transmission errors with a standard 6-bit $\overline{CRC}$ (hamming distance = 3). Error bit, warning bit and CRC bits are inverted before transmission (indicated with bar).

Safety Position Word (SPW)
The SPW is used to verify the CPW generation and transmission. Typically, it contains position information with a lower resolution compared to the CPW. Validity of the position can be indicated to the BiSS master with an error ($\overline{E}$) and a warning bit ($\overline{W}$). Additionally, an integrated 6-bit sign-of-life counter (LC) supports detection of missing or mixed up frames. Position, error bit, warning bit and sign-of-life counter are particularly protected with a safety capable 16-bit $\overline{CRC}$ (hamming distance = 6). Error bit, warning bit and CRC bits are inverted before transmission (indicated with bar).

FAILURE MODE DETECTION

The following data channel contents are required to detect failure modes according to IEC61784-3.

Redundant Position Data
The independent generation of redundant position data is the key to implement safe transmission systems. However, not all bits of the redundant position words need to be compared. In Table 1, ACC_{MIN} defines the minimum number of singleturn bits, which need to be suitable for comparison. The comparison of the CPW and SPW positions allows a +/- 1 LSB tolerance at ACC_{MIN}.

Error and Warning Bits
Error and warning bit enable the sensor to provide status information to the *BiSS* master. An error indicates that the transmitted position data is invalid. The meaning of the warning bit may be defined by the sensor manufacturer, e.g. to inform the drive about an upcoming required maintenance.

Cyclic Redundancy Check (CRC)
The CRCs of both CPW and SPW have to be checked separately. Different CRC polynomials are used to securely identify CPW and SPW. The 6-bit CRC polynomial 0x43 is used for CPW and the 16-bit polynomial 0x190D9 is used for SPW.

Sign-of-Life Counter (LC)
The sign-of-life counter is incremented with every newly generated BiSS Frame. It can be compared to an expected counter value to detect missing and mixed up frames.

TYPICAL DATA CHANNEL CONFIGURATIONS

Table 1 covers popular data channel configurations of rotary and linear encoders and their resulting minimum safety cycle time for SIL3. Further configurations and modified data contents require individual calculations.

Encoder	Type	MT_{CPW} 2)	MT_{SPW} 3)	ST_{CPW} 4)	ST_{SPW} 5)	ACC_{MIN} 6)	SCT_{min} 7)
Rotary Singleturn	RXM	0	0	16	12	9	31.25 µs
Rotary Singleturn	RXH	0	0	24	16	13	31.25 µs
Rotary Multiturn	RSM	12	12	16	12	9	31.25 µs
Rotary Multiturn	RSH	12	12	24	16	13	62.50 µs
Rotary Multiturn	RLM	24	24	16	12	9	62.50 µs
Rotary Multiturn	RLH	24	24	24	16	13	62.50 µs
Rotary Multiturn	RUM	12	0	16	12	9	31.25 µs
Rotary Multiturn	RUH	12	0	24	16	13	62.50 µs
Linear 1)	LMM	16	16	16	16	11	62.50 µs

Notes:
1) For linear encoder the total bit count results by adding the MT and ST bit count.

Abbreviations:
2) MT_{CPW}: multiturn information of control position word
3) MT_{SPW}: multiturn information of safety position word
4) ST_{CPW}: singleturn information of control position word
5) ST_{SPW}: singleturn information of safety position word
6) ACC_{MIN}: minimum number of singleturn bits, which need to be suitable for comparison (encoder accuracy)
7) SCT_{min}: minimum possible safety cycle time

Table 1: Suitable configurations for SIL3