A motor bridge module in the control system of harvesters

01 Motor bridge ESX-MBC

Authors: *Hans Wiedemann, Marketing Manager, Sensor-Technik Wiedemann GmbH*

Dietmar Caspers, Account Manager Krone, Sensor-Technik Wiedemann GmbH

The company Bernard Krone GmbH is amongst the leading manufacturers worldwide in agricultural technology. With the development of the BIG X 480 and the BIG X 580 they have set new standards for forage harvesters in this performance class. With 489 or 585 horse power, these modern agricultural machines fulfill a variety of applications, including harvesting maize plants for biogas or animal feed. In order to reliably execute various working functions, from the hydraulics through the drivetrain, right up to the chopping drum drive, the new forage harvesters are equipped with more than 20 interconnected control units. A large proportion of these units are connected to a central control unit, which enables automated coordination of working functions, and ensures safe operation. Slave modules, such as the ESX-MBC motor bridge, which have been developed in collaboration with Sensor-Technik Wiedemann (STW), fulfill dedicated tasks in as directed by an ESX master control unit.

The BiG X forage harvester family by Krone employs a complex control concept. Several bus systems connect the different control units and I/O units, and each bus system represents the respective functional domains such as the “motor bus” or Isobus. In order to communicate via the bus segments, individual control units also act as gateways. In such cases, only the specific data actually required there for the control tasks are transferred to the next bus segment. As a result, unnecessary data flow is prevented and the performance of the overall system is improved. The motor bridge module ESX-MBC, which acts as an I/O slave under the name KMB in the Krone BiG X 480 and 580, is assigned to the “Aux Bus” together with the ESX control unit. Both the ESX-MBC and the ESX control unit have been developed by STW in accordance with Krone’s requirements.

The motor bridge module

As a slave module, the ESX-MBC has a CAN bus interface. The CAN bus is used as a physical bus system for communication between the control unit and the ESX-MBC motor bridge modules using 29 bit-identifiers and provides transmissions speeds of up to 1 Mbit/s. As a superordinate protocol, SAE J1939, which is often used in commercial vehicles, is used here for the exchange of diagnostics and control data. The SAE J1939 protocol implemented by STW on the ESX-MBC supports both standardized and proprietary Parameter Group Numbers (PGN) and Suspected Parameter Numbers (SPN). It is processed on the 32-bit controller STM32F205 of the ESX-MBC. This controller has 128 kByte SRAM and 1 Mbyte flash memory, and therefore provides space for further functions which have been implemented by STW. The ESX-MBC receives commands from the ESX control unit for the adjustment of the four PWM half bridges which form the central function of the motor bridge module.

The four PWM half bridges, with PWM frequencies of up to 20 kHz, are assigned in two groups and can be combined to create two full bridges. Each half bridge has a 10 A output and electric motors or actuators up to approx. 200 Watt can be controlled. The outputs are short-circuit proof and capable of diagnostics, so that their status can be reported via the CAN bus to the ESX control unit. 2 half bridges and a 4A digital output respectively are connected to a power supply path, which can be switched off via an additional solid state safety relay. In each power supply path, current and voltage measurement is provided and an overload / overvoltage detection is included.

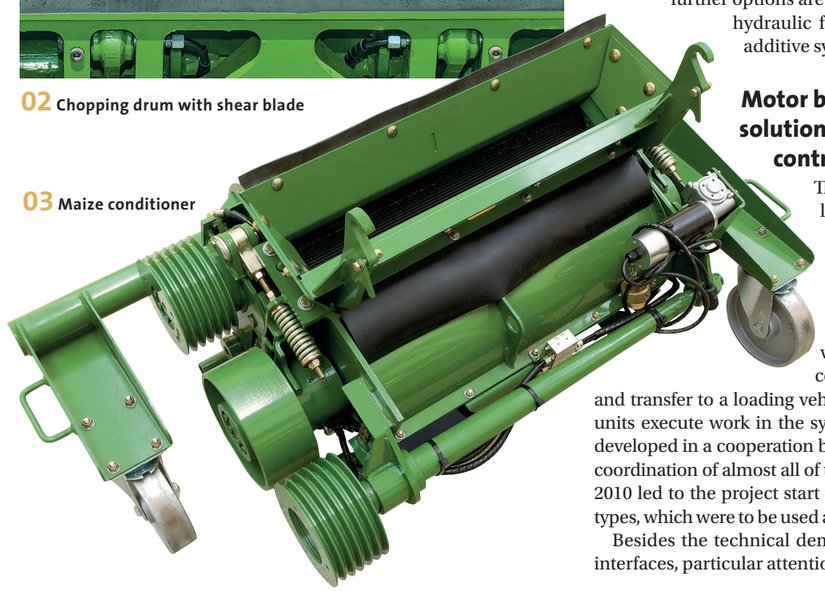
As an ESX-MBC also executes different tasks at different positions of the chopper, the module has an identification input. Through connection with resistors of different sizes, the software allocates the module its own “Source” address. Based on the source address the ESX control unit recognzies the task of the module and provides according instructions. Furthermore, the ESX-MBC has a 200 mA digital output which is also short-circuit proof and capable of diagnostics. In a range of 5 V to 12 V, a fixed voltage output adjustable via software supplies the sensors. Four multifunction inputs can be freely configured via commands as digital, speed, voltage or current inputs. Finally, a temperature measurement is available for the controller and the complete ESX-MBC. These functions of the ESX-MBC module are also addressable via the J1939 protocol.

The great strength of this module lies in the combination of intelligence and switching large currents. The possibility of flexibly using the ESX-MBC for different functions with the same hard- and software design, and continuously communicating status permits a high level of freedom in the system design and simplifies logistics. The module complies with the standards of the agricultural machine, construction machine and the automotive industries, which include especially shock and vibration resistance. The ESX-MBC provides sealing against water and dust according to IP67, is designed for a temperature range from -40 °C to +85 °C and has a connector suitable for mobile applications, ensuring uncomplicated installation.

The ESX-MBC extends the number of I/Os available, realising savings through less cabling for sensors and actuators. For example, the motor bridge is used in order to fulfill the specifications of the individual federal states regarding differing axle loads for road networks: The forage harvesters BiG X 480 and 580 can also be designed as 3-axle vehicles. In operation in the field, the third axle is not required and is hydraulically lifted. The control of the valves is also managed via the ESX-MBC.

Furthermore, the ESX-MBC is used for the regulation of clockwise and anti-clockwise rotation of the electric motors. These ensure the perfect adjustment of the shear blade of the cutter drum, which leads to high-quality chopping lengths and cutting quality of the crop. Thanks to the decentralized design using the ESX-MBC, further options are also realizable, for example additional hydraulic functions or the control of the silage additive systems.

02 Chopping drum with shear blade



03 Maize conditioner

Motor bridges as part of a complete solution / functions of the central control unit

The ESX-MBC is only one part of a far larger control system and this module is not the only new development. A new, higher performance central computer was also required for the extended requirements of the newly developed forage harvesters,. The vehicles execute complex tasks such as collection of the crops and processing and transfer to a loading vehicle. For this purpose, up to 20 control units execute work in the systems. The KMC 200, which has been developed in a cooperation between Krone and STW, takes over the coordination of almost all of these control units. The concept idea in 2010 led to the project start with strict planning for the first prototypes, which were to be used and tested during the corn harvest 2011.

Besides the technical demands on performance capability and interfaces, particular attention was placed on robustness, reliability and scalability. As specialists for solutions for mobile machines, STW had already established the ESX-3XL on the market. During discussions held between specialists of both companies, it was quickly determined that the ESX-3XL already provided an ideal hardware platform which could be adapted to the exact requirements of Krone by means of just a few modifications. Amongst other things, these adaptations regarded the interfaces for NAMUR sensors and two 10A half bridge outputs. Additionally, an outward and return line to all sensors and actuators is now provided. Thanks to its concept, which already provides a memory protection mechanism, and thanks to its design, development process and corresponding documentation and tests, the control unit ESX-3XL was already certified acc. SIL2 (IEC61508) and PLd (ISO 13849). As this project concerns a safety-relevant application, this represented an extremely valuable prerequisite for the tractor, agricultural and forestry machine standard ISO 25119.

The high-standard quality and production guidelines at STW were also regarded as positive. Mr. Horstmann, Electronics Manager at Krone, was also convinced by the overall impression made by STW during a visit: “It was particularly important for Krone to find a company in STW which, besides high technical competence, was also partnership orientated and thought and acted long-term. STW knows our market and has been successfully active here for over 30 years, and therefore we decided on STW as our development and production partner for the new control unit KMC 200 and the associated motor bridge modules”.

After Krone had decided on collaboration with STW in 2010, four companies subsequently worked under the leadership of Krone on the realization of this project. Besides the adaptation of the hardware, the adaptation of the BIOS for the 32-bit TriCore controller on the ESX control unit also fell to STW, which then eventually received the name KMC 200. In order to meet the performance and real-time requirements, the programming was executed in the language “C++”. At Krone, up to ten developers were ultimately involved in this project. Besides Krone and STW, partners included HighTec as provider of the certified operating system PXROS, and Brunel GmbH as development service provider. Close collaboration was essential in order to be able to correctly integrate the many control unit functions. “Today, we control chopper machines, grinding devices, feed units, attachments, ejection sections, corn conditioners and silage additive systems using the KMC – to name but a few! Meter readings are also recorded, and fill levels and filters monitored”, explains Mr. Horstmann. An important component of the development process is also the test cycle, in which firstly the individual software modules, which represent the different functions, are tested. Subsequently, a test of the application on the control units is conducted in an automated hardware and software integration test. Finally, a system test on the complete software is carried out on a machine. This is accompanied by the EMC trials in the test laboratory and the trials on test machines in real field applications.

About STW GmbH

Sensor-Technik Wiedemann GmbH, an internationally active company provides services and products in utilization of new technical possiblities in Automation, e-mobility and networking. The company develops and produces a wide range of products in control and automation systems, measurement technology, telematics and machine connectivity and electrification of drive lines and auxilliary drives. The company is based in Kaufbeuren, Germany and has annual turnover of € 50 million and employs 440 people.

After the prototype phase and deployment during the corn harvest 2011, it was possible to complete the development of the KMC 200 prior to the Agritechnica 2013. Here the first presentation and series launch of the BiG X 480 and Big X 580 took place, in which, besides the KMC 200, also up to four ESX-MBC motor bridge modules are employed. Markus Müller, Project Manager at STW, was responsible for both developments from the outset: “At STW, we especially value the excellent cooperation with the Krone team. This helped enormously in the process during which two products of this complexity were brought into series use in a relatively short period.”

The first milestone

This development is not yet complete, as long-term utilization is planned in further machines, but the first large milestone has been achieved. As a result of the concept which includes the distribution of tasks in the system architecture, re-usability of the components at hardware and software level is achieved. The use of the KMC 200 as a central control unit and the ESX-MBC motor bridge modules as dedicated and yet flexible slave modules, have already proven to be successful developments. Less than two years after the series launch of the BiG X forage harvester, STW received the Supplier Award from Krone as best supplier in the Electronics category.

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