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CAN-based tractor - agricultural implement communication ISO 11783

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The upcoming standard in the agricultural area for communications between a tractor and an implement (add-on equipment such as a thresher or a mower) is called ISO 11783 or Isobus in short. This standard forms the backbone of the autonomous agricultural machine system. The international standard consists of twelve documents ranging from definition of the transmission medium (Physical Layer) to application of the entire spectrum of serial communications based on CAN.

Specification work on this standard began early in 1991. Under the auspices of ISO (International Organization for Standardization www.iso.org) all activities are coordinated within the Technical Committee 23/Sub-Committee 19/Working Group 1. National committees and technical organization such as VDMA Landtechnik (Association of German Machine and Facility Building - Agricultural Equipment) perform some of the standardization tasks. Initial prototypes based on this standard were presented in November 2001 at an independent Isobus exhibit at the Agritechnica trade show in Hanover. At that show special attention was placed on its interoperability and compatibility between producers. Isobus was introduced in the USA in May 2002 at the AMC (Agricultural Machinery Conference) show in Cedar Rapids (Iowa, USA). The first tractors with tractor controllers were presented at that show. This development revealed broad acceptance of the standard by producers. A logical consequence of the observed trend toward increased use of electronics in tractors and implements is the networking of these components. The supplemental costs of networking represent just a small portion of the overall electronic development costs. Yet they have the potential of significantly enhancing performance of the total system. Only by networking is it possible to move toward the goal of achieving autonomous agricultural machines. Nevertheless, its advantages can already be realized today. Standardized networking permits multiple utilization of individual components in the network, and this reduces development costs. Automatic intervention into the tractor controller, e.g. to modify the operating speed or rounds per minute, permits more effective use of implements. For the farmer and user of the total system standardization also opens up the possibility of combining implements produced by different manufacturers with different tractors.

Data communication

The ISO 11783 standard is based on CAN, which has been used for a long time in the agricultural industry. The physical bus that is used is compatible with the SAE (Society of Automotive Engineers) J1939-11 standard. This is a passive two-wire bus terminated at the bus ends by a characteristic impedance. Each node

must be capable of being connected or disconnected during network operation. An active termination is used to achieve these plug-and-play properties. This means that the node at the end of the bus must automatically terminate it with the characteristic impedance to prevent reflections. The data rate is 250 kbit/s with a sample point of 80 %. Furthermore the entire implement - or at least the electronics - may be supplied with voltage over the bus. Voltages of 12 V or 24 V are permitted. The maximum total length of the bus is 40 m, whereby the length of possible branch lines is limited to 0.3 m. The number of nodes on a bus segment is limited to 30. The wiring used is a 4-conductor, unshielded, and twisted cable for the CAN network and the voltage supply to the controllers and to the active termination. Various types of connectors are defined with different functions: Implement connectors (Breakaway Connector), bus extensions (Bus Extension Connector) and diagnostics (Diagnostic Connector).
The entire Isobus is subdivided into at least two segments. The Tractor Bus is a segment, which permits communication within the tractor, e.g. powertrain, valves, etc. The second segment is the Implement Bus. This segment is available for communication between implement and tractor as well as between implements themselves. At least one Tractor ECU (electronic control unit) serves as the interface between the two segments. Communication on the Tractor Bus does not need to be ISO 11783-compatible. It is not even mandatory for the tractor to have a network. In practice the tractor controller represents a gateway between the two segments. It also controls the entire voltage supply for the implements. The voltage supply is subdivided into two parts: The supply for power electronics in the implement, and the supply for electrical controllers. For example, after ignition has been switched off, the voltage supply remains available to the controllers for a specified period of time. In the event of a communication failure the controller for the voltage supply can at least switch the hazard flashers on and off. However, a precondition for this is a suitable circuit on the implement side.
Communication on CAN is largely based on the SAE J1939 standard and has been harmonized somewhat to other standards. For example, it is possible to use devices from a SAE J1939 network under ISO 11783. Communication utilizes 29-bit CAN identifiers (extended frame format). Information is encoded in the CAN identifier, e.g. source address, target address and data contents, whereby two Protocol Data Units (PDU) are differentiated: PDU1 and PDU2. PDU1 format allows for peer-to-peer communication, and the PDU2 format for broadcast communication.
The signals to be transmitted are combined into Parameter Groups, and each group is assigned a unique Parameter Group Number (PGN). The Parameter Group definitions include the transmit frequency, priority and physical units of all signals. Since CAN limits the transmission to maximum eight byte, transport protocols are used for transmissions of more than eight byte. Broadcast Announce Messaging (BAM) and Connection Mode Data Transfer (CMDT) described in the SAE J1939 standard are supplemented by other transport protocols. For example, transmission of more than 16 MiB of data is possible with the Extended Transport Protocol. CMDT and BAM are limited to 1,785 byte. For the support of GPS (global positioning system) devices the Fast Packet Transport Protocol from NMEA 2000 is used.
Each node in the network gets a unique address in the range of 0 to 253. Network Management controls the assignment of addresses during boot-up of the nodes. Since nodes may have multiple connections to the network, e.g. the Virtual Terminal (VT), a fixed assignment of the address by the ISO standard is not possible. In this case the nodes need a separate address. These addresses are assigned with the help of the Address Claim Mechanism. Address conflicts between nodes are resolved by using unique device names, which at the same time describe each node's functionality. This allows all other nodes to recognize the functionality available in the network.

Virtual Terminal (VT)

The VT provides the user interface and therefore plays a significant role in the overall standard. Typically the VT has a screen and keys for the output and input of data. It must therefore satisfy a large number of requirements. These range from purely technical aspects, such as communication over CAN, to ergonomic requirements for its use. The ISO 11783 standard does not contain

any ergonomic requirements. This is a matter for the producer. The VT concept is based on the idea that all of the nodes in a network can share one or more of these VTs from which they can then interact with the user. From the perspective of the controllers the VT is exclusively available to each node. Masks are defined for the output and input of data, and these can be displayed on the VT. This information is provided by the controllers and not by the VT. This is comparable to an Internet browser where each controller can display elements. The screen is thereby subdivided into different areas. The Data Mask Area serves as the output unit for the masks. The Softkey Area provides labeling for assigned softkeys. The Data Mask Area must be square-shaped, whereby the minimum resolution is 200 x 200 pixel. The display may be black-white or color. For color displays palettes with 16 and 255 colors are defined. The 255-color palette is compatible with the 16-color palette. The controller alone is responsible for displays on the VT and user controls. This means, for example, that the controller must perform any scaling of the symbol sizes to a specific resolution. To assure readability of the masks on any VT, a controller can store a number of masks and then select a suitable one before transmission to the VT. Additionally, the VT provides functionality for identifying the hardware. For example, it is possible to poll the number of colors, screen resolution or number of softkeys. Working Sets are formed for communication between the controller and the VT. These consist of at least one node, the Working Set Master. The Working Set Master contains all information and control instructions needed for the input and output of data over the VT. The data are combined into an Object Pool for transmission to the VT. Optionally, the Working Set Master can save the Object Pool on the VT. In this case the Object Pool does not need to be retransmitted after a break in communication or system restart. Transmission can be especially time-consuming for large Object Pools (>500 KiB) where the transmission may take anywhere from several seconds to minutes. Individual elements of the Object Pool are identified by unique identifiers, the Object IDs. Exactly one Object Pool is possible per Working Set. An Object Pool may consist of several masks, which are output on the VT's screen. Special graphic elements such as a meter object, line, rectangle, circle, dot or input/output boxes for text and numbers are available in the Object Pool. The Object Pool is defined hierarchically. Individual objects may be combined into a Container. The Container and all of its objects may be shown or hidden. It is still possible to change an object's properties after they have been defined, e.g. its color or position. Alarm masks are supported for critical events. If necessary the alarm masks can be displayed automatically in the VT's foreground. The user must acknowledge them. This is a way to implement warnings or error messages, e.g. when upper or lower limit values are exceeded. Another special feature of the VT concept is the support of Auxiliary Inputs. These are supplemental input devices, e.g. a joy-stick on the arm rest or a screen button. It does not matter whether the Auxiliary Inputs are housed directly at the terminal or are connected afterwards over the Isobus. The VT automatically detects the Auxiliary Inputs. The user can configure functions of the Object Pool to these input devices without having to anticipate their later addition when the Object Pool is created

Tractor Controller (ECU)

The Tractor ECU represents the communication interface between the Implement Bus and Tractor Bus. Consequently the Tractor ECU assumes a central role in

Tractor - Implement communication. A communication interface was needed because no uniformly defined interfaces existed for the Tractor Bus. Therefore Part 9 of the ISO 11783standard describes this interface. The Tractor ECU is essentially subdivided into the classes 1, 2 and 3. These classes differ in the functionality they offer. A higher class must satisfy all properties of the lower class. If only some functions of a class are satisfied then the next lower class automatically applies. Based on the specified Tractor Class the user can recognize whether or not an implement may be operated on a tractor. This means that an implement requiring information of a Class 2 Tractor ECU will work together with a Class 2 and 3 Tractor ECU. A Class 1 Tractor ECU makes basic information available. This information can be further classified into: power management, speed information, hoisting gear, power take-off shaft, lighting control (signal lights and running lights) and information on the language used. Power management information includes information on the momentary position of the ignition and voltage supply for the implements. Speed information includes wheel-based speed and ground-based speed as well as the engine RPM. The hoisting gear information includes the momentary position of the internal hoisting gear and signaling of the working point. Information on the power take-off shaft includes rotational speed and output engagement. The lighting information indicates the states of the signal lights (flasher and stop lights) and running lights. The language parameter includes information on the language being used. The Class 1 Tractor should no longer be used in new developments. Primarily, it serves to support systems in which the Isobus is being retrofitted. A Class 2 Tractor ECU transfers more information, permitting better implement adaptation. The supplemental information compared to Class 1 is information on time and date format, distance and direction information and the pulling force at the rear hoisting gear. Furthermore, a Class 2 Tractor permits control of the implement's entire lighting system. Moreover, value states are also communicated.
A Class 3 Tractor permits commands from the Implement Bus to the Tractor ECU. These commands include the position of the rear hoisting gear, power take-off shaft speed, Speed Set Point and Engagement as well as control of valves. For all classes there is the optional capability of having the Tractor ECU provide GPS navigation information. Since the implement accesses it, the tractor holds Class 3 security risks. Therefore certain general ground rules should be observed as described below:

- An implement must not start itself independently, since otherwise nearby persons might be injured.
- Execution of a Stop command by the user must not be suppressed.
- When a Stop is executed no part of the implement should drop down or be ejected.
- The user must have the opportunity to overwrite commands.

In real systems the Tractor ECU assumes yet other tasks, which will not be discussed here in any detail, e.g. filtering of messages between the Tractor Bus and Implement Bus, passing of messages, checking of the received commands and resolution of access conflicts.
The Task Controller is a controller that can be used to assume the control of implements. Before executing a job data are fed into this ECU, which are then transferred to an implement in the field. An example of this is the control of output volume when fertilizing as a function of location. The Task Controller essentially supports three operating modes: Time-based, distance-based and location-based. A special parameter group is available for controlling implements and exchanging data.

Summary

The international ISO 11783 standard offers the technical capability of uniformly exchanging data and control commands between a tractor and implement. A uniform test method is needed to ensure that the interfaces in this system will be compatible across producers. Currently various activities are being conducted by independent organizations to set up such a uniform test method. The large number of producers who have already announced products conforming to this standard or who already have finished implementations suggests that the standard is finding acceptance among producers. Once the advantages of this technology have been communicated in the marketplace, there should be no more obstacles to its broad acceptance.

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