

CAN in agriculture and farming

(Source: Adobe Stock)



The world human population is growing. CAN was helping, is helping, and will be helping to provide people with food and beverage.

Agriculture is the practice of cultivating plants and livestock. The history of agriculture began thousands of years ago, when humans started to settle down: Nomadic gatherers and hunters turned into arable farmers, cattle breeders, and sedentary fishermen. In the ancient high cultures, agriculture technology was developed to enable the building of cities and monuments. Not everyone was involved in the production of food. There were a lot of workers and administration staff.

Nowadays, the farmers need to feed about eight billion of people. This can only be achieved when using sophisticated technology including electronic-controlled and automated machines. Smart farming is the buzzword: It has a real potential to deliver a more productive and sustainable agricultural production, based on a more precise and resource-efficient approach. It comprises agricultural automation and robotics, precision agriculture, and management information systems.

Isobus and its predecessors

Already before CAN was invented, German engineers discussed and developed the LBS (landwirtschaftliches Bus-system; engl. agriculture bus-system) network approach for connecting electronic equipment within agriculture machinery. When CAN was introduced in 1986, the LBS specification adapted this serial network technology and standardized it in DIN 9684/2-5. But it was not flying due to some technical issues regarding the physical layer specification. Additionally, the North American farming industry was in favor of the J1939 CAN-based network technology, originally developed for commercial road vehicles. The result of the worldwide harmonized and joint development on both sides of the Atlantic Ocean is well-known: Isobus, internationally standardized in the ISO 11783 series, is worldwide used to connect tractors and implements. Implements is the name for any kind of attached machinery: sprayers, fertilizers, harvesters, etc.

One of the most important benefits is the development of the virtual terminal (VT) approach. It allows using the truck-mounted display for all connected implements. The VT communicates via the CAN-based Isobus network with the implements. The farmer controls the implements

via the VT and the implements provide status information to the VT.

The development of the Isobus technology started mid of the 90ties. In 2001, first machinery using it arrived on European farms. Today, there are many implements with an Isobus interface. The [CAN Newsletter Online](#) reports regularly about new product developments and the progress of the 14-parts ISO 11783 standards series.

Table 1: Isobus standards overview

| Part-no. | Title | First issue | Current issue |
|--------------------------------------|--|-------------|-------------------|
| 1 | General standard for mobile data communication | 2007 | 2017 |
| 2 | Physical layer | 2002 | 2019 |
| 3 | Data link layer | 1998 | 2018 |
| 4 | Network layer | 2001 | 2017 ^a |
| 5 | Network management | 2001 | 2011 ^a |
| 6 | Virtual terminal | 2004 | 2018 |
| 7 | Implement messages application layer | 2002 | 2018 |
| 8 | Power train messages | 2006 | 2015 |
| 9 | Tractor ECU | 2002 | 2012 ^a |
| 10 | Task controller and management information system data interchange | 2009 | 2015 |
| 11 | Mobile data element dictionary | 2007 | 2016 |
| 12 | Diagnostics services | 2009 | 2019 |
| 13 | File server | 2007 | 2016 |
| 14 | Sequence control | 2013 | 2018 |
| ^a under systematic review | | | |

Associations promoting Isobus

There are several associations, which help to promote the development and to increase interoperability of Isobus-based applications. SAE (Society of Automotive Engineers) develops and publishes J1939-based standard series referenced by Isobus specifications. AEF (Agri-▷

cultural Industry Electronics Foundation) is the nonprofit association promoting and pre-developing the Isobus protocols. The AEF members jointly work on interoperability solutions. The foundation also proves and certifies devices in so-called Isobus plugfests. The CC-Isobus is a joint development activity of several implement manufacturers, which develop and provide a broad portfolio of VT products. Established in 2009, this competence center has designed the CC-I 1200 terminal, for example, which has been installed more than 50 000 times. DLG (German Agriculture Society) organizes the worldwide biggest Agri-technica tradeshow in Hanover (Germany). The awards, conferred by a committee of experts appointed by the DLG, recognize leading technologies and new developments in the agricultural equipment and machinery sector.

Embedded machine control

Agriculture and forestry machines are equipped highly with electronics. These include the Isobus backbone networks connecting electronic control units (ECU) and additional sub-layered embedded CAN-based networks. Some of them use proprietary application layers, while others are based on J1939 or CANopen.

As some recent examples, Actia offers the SPU40-26 safety power unit with an ISO 11783 compliant interface, which has been certified and proved by AEF. B-Plus has a range of CAN- and Isobus-capable development tools, measurement technology, as well as several controllers in its product portfolio. Bernecker + Reiner, Epec, ifm electronic, Intercontrol, and STW provide host controllers with Isobus-connectivity. They are linked via the CAN interface with the operator displays. Some of them support the virtual terminal function (VT).

Syslogic offers AI (artificial intelligence) PCs with a J1939 (FD) interface and Crosscontrol offers terminals with a CAN FD interface. These provide a higher throughput than the current Isobus or proprietary Classical CAN interfaces. But some farmers prefer traditional tablet computers as user interface. Such solutions are offered e.g. by Reichardt. Ruggedized J1939-connectable in-vehicle telematics tablets are offered by Waysion Technology, Zhangzhou Lili-pit Electronic Technology, and Ruggon.

TTCControl's HY-TTC 500 controller family with three CAN interfaces meets safety standards up to EN ISO 25119 Ag PLd, IEC 61508 SIL 2, and ISO 13849 PLd. A

typical Isobus-compliant job controller platform is the APC mobile 3100 by Bernecker + Reiner. The company's X90 controller features a CANopen Safety interface. This safety-related network can be used for implement-internal control purposes.

Smart work-light system

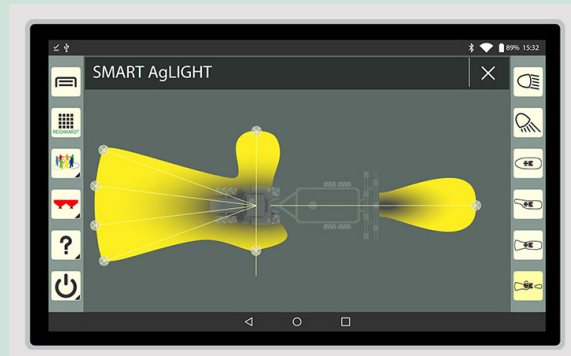


Figure: Direct and indirect glare can be avoided and work areas can be optimally illuminated, even in a vehicle combination. Here, the area to the left of the vehicle is dimmed accordingly for a vehicle driving alongside. (Source: Reichhardt)

The Smart Aglight by Reichhardt is able to distribute light continuously for long-distance and close-range lighting by individually controlling and networking the diffusing lenses of the work-lights. Precise, storable light profiles are adapted to equipment combinations and operating conditions. The lights are operated via an ISO-VT (Isobus virtual terminal) or wireless via mobile terminals, which allows to use smartphone apps and further functionalities. Existing machines can be retrofitted. The recognition of the implement via Isobus adapts the light field to the machine combination. Using a wireless link, the light profiles of several vehicles can be interlinked. Thus, direct and indirect glare is avoided and the working areas are optimally illuminated.

Camera systems for process monitoring and safety in semi-autonomous machines or in field robotics are also supported. In combination with mobile communications, Bluetooth, or Wifi, features such as coming-home or wake-up functions via cell phone or tablet are possible as well.

Controller for agricultural machinery

TTCControl lately developed the Isobus-compatible TTC 2300 ECU (electronic control unit) series for off-highway machinery, such as agricultural implements, harvesters, farm tractors, and hybrid electric vehicles. The series is scalable according to advanced and automated off-highway applications. It is designed to be the heart of a centralized electronic architecture and can serve as a vehicle control unit (VCU), a safety monitor, or a head-unit controller for agricultural implements.

The controllers are TÜV safety certified and meet safety standards from the agricultural, construction, and

automotive industries, said the company. They are designed for communication with IoT (Internet of Things) networks. The ECUs provide processing of information from analog, digital as well as smart sensors and are able to control electric motors and further actuators.

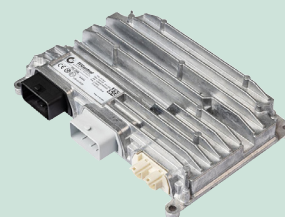


Figure: The controller is built for use in rugged operating environments (Source: TTCControl)

Optimized tractor control: TIM

The TIM (tractor implement management) function allows the implement to send commands to the tractor. In this way trailed machines can control functions such as PTO (power take off) shaft, lifting gear, driving speed, steering angle, or hydraulic valves. Thus, the combined machinery automatically adjusts to the current situation reducing the operator's burden, increasing machine performance, and productivity. Several tractor manufacturers already integrate TIM in their vehicles and implements. Fendt, Krone, John Deere, Kubota (Kverneland), Lemken, and Claas are just some examples.

TIM was originally invented by John Deere and is further developed by AEF. First TIM solutions were introduced at Agritechnica 2009. At that time only the machines of the same manufacturer could exchange data. With the release of the TIM specification version 2, the implement sends information to the tractor via a standardized and secure communication. Nowadays, it is a cross-product and cross-manufacturer solution i.e. a tractor-implement combination from different manufacturers is possible. Using Isobus-tested devices with the TIM function (certified by AEF), farmers expect that the coupling of the tractor and the implement works in a plug-and-play manner.

Awarded Isobus solutions

On the Agritechnica tradeshow in 2019, DLG has awarded several Isobus solutions. For instance, the automated tractor and implement [guidance system for wineyards](#), which was jointly developed by Fendt and Braun. The ground contour, vines, poles, etc. are recorded using laser technology and the information is passed on to the tractor via the Isobus interface. Additionally, the 3D position is determined with a gyroscope and the tractor assumes the track and implement guidance based on this information.

The [Isomax solution](#) by CNH Industrial global agricultural brand New Holland is a hardware and software interface compliant with ISO 11783 series. All hardware components are AEF certified, all software is open source, and the system is compatible with all brands. System features include automatic implement recognition to facilitate operation.



Figure 1: The awarded automated vehicle by Fendt and Braun (Source: Fendt/Braun)

Additionally, the IQblue retrofit TIM solution by Lemken was awarded. Deploying a GPS receiver, it allows users to automate agriculture machines for ploughing, cultivating, tilling, etc. Another winner was the Nevonex open Isobus platform powered by Bosch. Like an operating system, it forms the basis of software applications to program new and legacy machines. An integrated interface management enables optional access to the platform via the Isobus.

John Deere reveals a fully autonomous tractor



Figure: The 8R tractor uses cameras and artificial intelligence to navigate (Source: John Deere)

Already in 1837, Deere & Co. helped mechanize agriculture with the first commercially successful steel plow. At the CES 2022, John Deere revealed a fully autonomous 8R tractor combined with a chisel plow, GPS guidance system, and artificial intelligence technologies.

The autonomous tractor has six pairs of stereo cameras, which enables a 360-degree obstacle detection and the calculation of distance. Images captured by the cameras are passed through a deep neural network that classifies each pixel in approximately 100 milliseconds and determines if the machine continues to move or stops, depending on if an obstacle is detected. The tractor is also continuously checking its position relative to a geofence, ensuring it is operating where it is supposed to, and is within less than an inch of accuracy.

To use the autonomous tractor, farmers need to transport the machine to a field and configure it for autonomous operation. Using a smartphone app, they can start the machine. While the machine is working the farmer can leave the field to focus on other tasks, while monitoring the machine's status from their mobile device. John Deere Operations Center Mobile application provides access to live video, images, data and metrics, and allows a farmer to adjust speed, depth and more. In the event of any job quality anomalies or machine health issues, farmers will be notified remotely and can make adjustments to optimize the machine performance.

"It's a monumental shift," said Jahmy Hindman, Deere's chief technology officer, of the new machine. "I think it's every bit as big as the transition from horse to tractor."

From automated to autonomous

Autonomy has been creeping into tractors and other farm equipment for decades, with recent advances building upon progress in robotics and self-driving cars. Advances in sensing, communication, and control technologies coupled with global navigation satellite systems (GNSS) and geographical information systems (GIS) enable tractors to become automated or even autonomous. Self-driving tractors could help save farmers money and automate work that is threatened by an ongoing agricultural labor shortage. The gathered data about the soil and precision farming applications help to enhance productivity and optimize resource efficiency.

The increasing autonomy requires additional sensors connected to the CAN-based in-vehicle networks. Typical examples include cameras, 3D sensors, and GNSS systems. GNSS-supported steering systems are already used in daily farming work. Due to real-time kinematics (RTK), intervention is no longer required when the farmer has to line up their tractor or other self-propelled machines such as sprayers, choppers, and harvesters with the next track with an accuracy of two to three centimeters. Of course, the steering wheel needs to be moved by an electric motor. For instance, Reichardt provides the PSR Advanced automatic steering system using GNSS, low-wear synthetic tactile sensors, and ultrasonic sensors. It includes an Isobus terminal as well as several panel-apps and can be used for retrofit applications.

Self-steering tractors have existed for some time now. Hereby, the tractor does most of the work, with the farmer stepping in for emergencies. The technology is advancing towards driverless machinery guided by GPS. Recently, John Deere already introduced the fully autonomous 8R tractor. Further tractor manufacturers are expected to follow.

CAN in animal farms

CAN-based networks are embedded, and thus invisible for “outsiders”, in many applications for livestock cultivation e.g. in cowsheds, pig farms, and poultry barns. Already mid of the 90ties, CAN networks were used in cowshed carousels. They connected feeding equipment and devices measuring the water amount the animals were taking. Today, service robots feed and serve animals with increasing autonomy.

For example, the Netherlands-based company Lely manufactures robot milking systems. The CANopen-interconnected Lely Astronaut A4 milking robot including a mechanical arm and teat-cleaning equipment, can handle about 180 milkings a day. The system is trained to prepare the cow for milking, to (re)attach the teat cups, to detach after milking, and to carry out post-treatment. The walk-through functionality allows the cow to walk straight in and out of the milking box without making turns. The animals go into the milking box on their own because they know there is food in the form of a measured amount of grain. The milk quality can be measured, monitored, and diagnosed using the CANopen-based MQC (milk quality control) tool. This provides the user with vital information on

mastitis, fat and protein, and lactose for managing milk quality and cow's health. Alarming deviations are noticed and reported. Lely partnered with Strypes (Netherlands) to develop this remote monitoring and diagnostics software solution.



Figure 2: After going in the box the robotic arm moves under the cow, scans it with lasers to find the teats, and attaches four teat cups (Source: Lely)

Another solution to create an easier workplace for milkers is the MDS Saccomatic IDC by the Danish company SAC. This milking control unit communicates via CANopen and registers milking and milk flow, gathers milking data, and displays the required data. It can be extended and connected to a cow identifier and a milking management system to process data from the milking parlor. To ensure that the operator has a complete overview of the milking parlor, the IDC can be connected to touchscreens. In case of a problem, a “cow-related” alarm flashes on the screen. The milker with a few moving parts can also measure the electrolytic conductivity of the milk. This makes it possible to diagnose mastitis in an early stage so that the dairy farmer can begin treatment to prevent the inflammation from spreading.

In a further example, the German company GEA is providing an automated rotary milking parlor Dairyproq, which also uses embedded CAN communication. For milking, the cow steps straight onto the rotary milking parlor where the Milkcrack system automatically attaches the teat cups thanks to a 3D camera. The solution allows an undisturbed milking process, said the manufacturer. Also here, the conductivity sensors monitor every udder quarter, which allows to gather information about the milk quality and to manage cow's health preventively. Using the monitoring software GEA Farmview, the automated milking system can be checked via online diagnosis.

The German company Weda provides CAN-connectible stable climate control solutions for pig farms. The Veco.Mate product range includes control systems, alarm units, and power supplies. The controller with a touchscreen provides connection options for reading probes, sensors, measuring fans as well as for setting and controlling of hatches, fans, heaters, valves, etc. It records the climate condition values (temperatures, humidity etc.) for up to 12 months. Via the integrated LAN (local area network) interface, the computer can be operated via a PC or a smartphone using the integrated web server. The alarm computer manages up to 16 separate alarms triggered by ▶

detecting of abnormal conditions. The power supply units developed for agriculture use integrate two rechargeable batteries or a 230-VAC unit, which maintain the output voltage in a power-failure event. If the unit is connected to the alarm computer, the user is automatically informed about a power failure.

Hotraco Agri (Netherlands) is a supplier of computer-based control and monitoring systems for pig and poultry farms. These include HVAC (heating, ventilation, and air conditioning) systems, feed and water control, animal weighing, and egg counting. The control systems use internally CAN networks. Via an up to 500-m CAN backbone network, it is possible to connect several controllers in different houses. CAN switches with four ports are used to bridge the backbone to the local in-house CAN or CANopen networks. For poultry barn ventilation and air conditioning, pad cooling and nozzle systems are used. The Mira-P poultry computer manages and controls all common barn situations and processes, such as ventilation, heating, cooling, the registration of feed and water, as well as weighing of birds. Cascaded via CAN, the Mira-P controllers can be connected to the Smartlink gateway. The latter allows access to the controllers via a PC or a smartphone.



Figure 3: The control systems for poultry farms include HVAC (heating, ventilation, and air conditioning) systems, feed and water control, animal weighing, and egg counting (Source: Adobe Stock)

Farming robots are coming

In recent years, agricultural robots have moved into smart platforms providing physical interaction with the environment. Unmanned agricultural ground vehicles (UAGVs) have a huge potential to optimize crop yields and increase sustainability. For example, some already available automated guided vehicles use electrical motion controllers with CANopen interfaces by Maxon or Dunkermotoren.

Robotic and artificial intelligence are used to improve precision of the crop irrigation. Agricultural robots enable weed monitoring and control in spite of variability in the field conditions. The involved perception systems can detect and classify weed plants from crop plants, and weed control mechanisms cover both chemical and mechanical weed control. In orchard operations, robotic technologies are used for major tree fruit production tasks, including robotic pruning, thinning, spraying, harvesting,

and fruit transportation. Mechanical harvesting machines such as canopy and trunk shakers are widely used for collection of some crops. These machines incorporate artificial vision systems to perform a pre-grading of the product in the field. For example, harvest-assist platforms in citrus orchards are capable of both inspecting collected fruits and separating them into categories.



Figure 4: In-built perception systems allow robots to inspect and collect ripe fruits (Source: Adobe Stock)

Collaborative robots (Cobots) and robot swarms are mainly in prototype and research status. Small automated and self-propelled units instead of a big machine are the trend. For example, the grubber is no longer a single unit with a 9-m working width. Instead, several smaller units are interconnected wirelessly. Thus, depending on the field size, it is not necessary to provide the maximum capacity in every case.

The growing number of robotic milking installations on farms has been driven by the need for better labor management and improved quality of life for dairy producers. The robotic milking systems (RMS) on farms consider barn design, feeding management, and udder health in automated systems. The trend towards robotic milking is set to continue into the future. Automation in meat processing operations is challenging, as the robotic systems have to deal with deformable biological products that lack uniformity. Some advances in robotic automation are achieved for the processing of fish, beef, pork and lamb, as well as poultry.

Future trend: Precision agriculture

Precision agriculture is a farming management concept, which considers the different potential soil productivity inside of a field. It is based on observing, measuring, and responding to given field conditions. The goal is to enhance productivity and optimize resource efficiency. Involved technologies include GPS (global positioning system), GIS (geographical information system), and GNSS systems. The ability to locate the precise position in a field allows for the creation of spatial maps for such measured variables as crop yield, topography, moisture levels, nitrogen levels, pH, and others.

This data can be collected by CAN-connected, real-time sensor arrays mounted e.g. on GPS-equipped combine harvesters. In conjunction with satellite imagery, the data is used by variable rate technology (VRT) ▶

including seeders, sprayers, etc. to optimally distribute resources. Recent technological advances have also enabled the use of real-time sensors directly in soil, which can wirelessly transmit data.

Precision agriculture is also enabled by unmanned aerial vehicles (drones), which can include CAN-based networks. These agricultural drones can be equipped with



Figure 5: Equipped with cameras, the agricultural drones capture multispectral field images to build precise topography maps used to correlate crop health with topography (Source: Adobe Stock)

cameras to capture multispectral field images used to process and analyze vegetative information. Providing of additional geographical references such as elevation allows to build precise topography maps used to correlate crop health with topography. The correlation results help to optimize crop inputs such as water, fertilizer, herbicides, and growth regulators through variable rate (VRT) applications.

The IoT (Internet of Things) technology comes into play with the interconnection of sensors and the farm-management software. Via web-based applications the farmers can gather precise information about the field conditions and react on them correspondingly. Smartphones and tablets are increasingly used in precision agriculture as they come with helpful applications (e.g. camera, GPS, accelerometer) and are portable, affordable, and have a high computing power. Dedicated agriculture applications such as field mapping, tracking animals, obtaining weather, and crop information can also be installed. A variety of agricultural machine manufacturers provide smartphone applications to control and monitor of some tractor and implement functions.

These innovations can also be used for the welfare of animals. Cattle can be outfitted with internal sensors to keep track of stomach acidity and digestive problems. External sensors track movement patterns to determine the cow's health and fitness, sense physical injuries, and identify the optimal times for breeding. All this data from sensors can be aggregated and analyzed to detect trends and patterns.

The machine learning technology (artificial intelligence) uses the data input from different sources to process the information and to control the actuating machines in the optimized way. It may also provide predictions to farmers at the point of need, such as the contents of plant-available nitrogen in soil, to guide fertilization planning. As agriculture becomes ever more digital, machine learning will underpin efficient and precise farming with less manual labor.

IoT gateway for agriculture vehicles



Figure: Claas and Liebherr co-operate regarding IoT applications (Source: Liebherr)

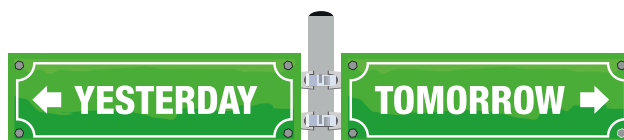
Claas, the manufacturer of agriculture machinery, uses the programmable IoT gateways by Liebherr in its combine harvesters, forage harvesters, and tractors.

The IoT gateway links Claas' digital services with the CAN-based in-vehicle networks using Isobus protocols. The web-based digital services include data management and precision farming. While tilling the fields, the machine continuously collects data and saves it in the cloud, so that the farmer can access it for future optimization. This data collection enables the targeted management of agricultural land by means of adapted fertilization and regulation of the sowing rates. The real-time remote diagnosis capability in case of a fault, maximizes the machine's availability. Every day, tens of thousands of Liebherr IoT gateways ensure the efficient connection of machines worldwide.

Outlook

Machine vision, navigation, actuation, communication, and control technologies help to save labor, improve precision and enhance efficiency in agricultural operations. CAN plays an important role for interconnection of the sensing, actuating, and controlling equipment. In sophisticated agriculture machines, there are up to ten CAN networks. In the future, also this industry will backbone such networks by means of an Ethernet network. AEF is working on an Ethernet-based high-speed Isobus. CAN FD and CAN XL may also be considered for embedded implement communication.

More and more farms around the world are automated. Current agricultural robotics systems are still limited and fully robotized farms are not yet available. Should more autonomous robotic systems become feasible, the role of humans in agriculture will not be eliminated. Humans will still be needed for supervision and collaboration. ▶

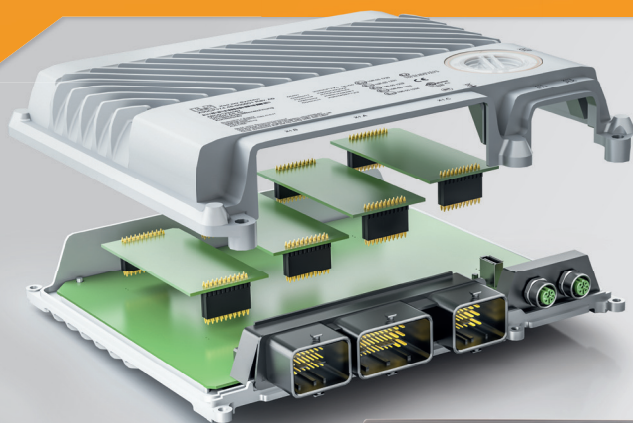


The agriculture industry, powered by the work of machines, increases the need for IoT-based smart solutions. Precision agriculture is an application of digital farming technologies such as satellite navigation and imaging, robotics, IoT, and machine learning. Observing, measuring, and responding to given field conditions, precision agriculture enhances productivity and optimizes resource efficiency. This is increasingly required in the future to satisfy the growing demand for food and beverage. ◀



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