# CAN-connectable joysticks and foot pedals

Since CAN-based control systems are used in mobile machines and off-road vehicles, it is necessary to connect human machine interfaces such as joysticks and foot pedals directly to the embedded CAN networks. In the beginning, most of the CAN-connectable joysticks implemented proprietary higher-layer protocols or provided just layer-2 services. In the meantime, standardized joystick profiles are available for CANopen and J1939.

Historically, joysticks were designed for aircrafts and elevators. The first electrical 2-axis joystick was invented in Germany during the World War II. The device was developed for targeting a glide bomb against ship targets. An operator used the joystick to steer the missile towards its target. This joystick provided on/off switches rather than analog sensors. The signal was transmitted from the joystick to the missile via radio. In the 1960s, the use of joysticks became widespread in radio-controlled airplane models. The Atari joystick with a single 'fire' button was the de-facto standard digital joystick specification in the computer business, before in 1985 Nintendo reinvented the joystick and integrated it as an add-on in its game consoles.

Nowadays, industrial joysticks provide two- or three-dimensional analog values and several digital inputs and maybe some LEDs. In the meantime, there is a recommended practice for using the CiA 401 CANopen device profile for joysticks (see insert "CANopen joystick profile") available as well as some dedicated PGNs (parameter group number) for J1939-supporting joysticks (see insert "J1939 joystick messages"). This simplifies system integration of joysticks into CANopen and J1939 networks. There are quite different functional requirements: Besides simple, compact joysticks, in some applications joysticks with several position states are needed. Often the joysticks are designed on specific customer demands.

DeltaTech Controls and Penny+Giles Controls serve the largest OEM's like Caterpillar, John Deere, Agco, CNH, JLG, and others. Penny+Giles Controls also designs and manufactures joysticks for Sauer-Danfoss. Apem is another such manufacturer for the global market, incorporating the brands CH Products, Oliver Control Systems, and Apem. There are also other North American suppliers such as OEM Controls, Otto Engineering, PQ Controls and CH Products. In Europe, there are several manufacturers that supply specialized market sectors, such as crane controls, construction machines, etc. The larger manufacturers of joysticks are able to customize joystick handles and grips specific to the OEM needs, while the small regional producers concentrate on selling standard products (with standardized interfaces) to smaller OEM's.

## Single-chip joystick interface

Standardization of CAN interfaces for joysticks allows developing a single-chip, pre-programmed microcontroller following a com- ▶

### CANopen joystick profile

The CiA 401 CANopen device profile for generic I/O modules specifies in an annex, how to use it for joysticks. If the device follows the recommended practice, the designer must indicate this in the device type parameter. Besides the profile number (401), this parameter indicates in the specific function bits (31 to 24) which kind of joystick is implemented. There are three options specified: Joysticks using the normal CiA 401 PDO mapping, a 2-D joystick mapping, or a 3-D joystick mapping. Bit 23 indicates if one of the standardized PDO mappings is implemented or a manufacturer-specific one. The generic PDO mapping uses the first TPDO for the digital information and the second TPDO for the analog values. The other two standardized mappings are shown in Table 1 and Table 2. By default, all TPDOs are scheduled event-triggered (when one of the mapped process data changes).

The joystick is configurable by means of SDO services. This includes communication parameter (e.g. synchronous PDO transmission) and application parameters, such as analog input dead-band as well as analog pre- and post-scaling. In general, the flexibility of the CANopen protocol is higher than of J1939.

*Table 1: CANopen TPDO mapping for 3-D joysticks*

| TPDO | Scheduling | Byte | Mapped parameter |
|---|---|---|---|
| 1 | Change of state | 1 | 8 digital inputs (6000 $01_h$) |
| | | 2 | 8 digital inputs (6000 $02_h$) |
| | | 3 + 4 | Z-dimension (6401 $03_h$) |
| | | 5 + 6 | Y-dimension (6401 $02_h$) |
| | | 7 + 8 | X-dimension (6401 $01_h$) |

*Table 2: CANopen TPDO mapping for 2-D joysticks*

| TPDO | Scheduling | Byte | Mapped parameter |
|---|---|---|---|
| 1 | Change of state | 1 | 8 digital inputs (6000 $01_h$) |
| | | 2 | 8 digital inputs (6000 $02_h$) |
| | | 3 | 8 digital inputs (6000 $03_h$) |
| | | 4 | 8 digital inputs (6000 $04_h$) |
| | | 5 + 6 | Y-dimension (6401 $02_h$) |
| | | 7 + 8 | X-dimension (6401 $01_h$) |

munication profile. For example, Frenzel & Berg offer the CO4013 chip implementing the CANopen joystick profile with up to four axis and additional digital I/Os. The implementation of the CANopen protocol is completely accomplished and tested. Programming of the joystick-chips is not required. The adjustment of bit-rate and node-IDs is done by means of external circuitry.

Certification is an important issue, when implementing a standardized joystick profile. CiA certifies CANopen products. J1939 compliant joysticks are not certified by an independent organization, but the manufacturer may self-certify its product using tools from third-party suppliers. The UPC230 joystick by Walvoil, an Italian company specialized in mobile hydraulics, is such a CiA-certified CANopen device. It is designed to be used in off-highway machines to control hydraulic components like valves, pumps and transmissions. Those devices require to work in harsh environments with an operating temperature range of -30 °C to +70 °C, to be packed in IP65-rated housings, and to be EMC-tested according to ISO 13766. The device by Walvoil is a two-axis joystick with an integrated push button on the knob and two additional buttons on the base. It can be used to control a valve with up to five sections (four proportional and one on-off). Alternatively the three buttons can be used to activate auxiliary functions on a two sections valve or to set operating modes like float, fast/slow, and continuous flow. The CANopen interface supports one TPDO containing the values of the two proportional axis (X and Y), the joystick center detect status (redundant neutral position signal), the three push-button status (with integrated debouncing), and a manufacturer-specific diagnostic error code. It can be programmed to enter automatically the NMT operational state (so-called self-starting device). In NMT pre-operational state it is possible to calibrate the X and Y outputs to get the best proportional range from the valve.

## CiA 401 and SAE J1939-71 support

Many joystick vendors provide CAN interfaces supporting CANopen as well as J1939 or just one of them. Some joysticks run proprietary application layers such as IQAN by Parker. Of course, Parker has implemented this higher-layer protocol in its IQAN-LC5 joystick devices. They have been developed for load handling and positioning applications in both in-cab and on external vehicle surfaces.

At the Bauma, William Controls introduced a joystick family featuring J1939 and CANopen interfaces. The products provide an X and Y position output. The ball and socket pivot design reduces moving parts by 60 %, relative to comparable products. As most of the joysticks, the devices use Hall-effect non-contact technology, which provides a solid-state electronic system that will provide reliable performance over the 20 million cycle life. The joystick can be configured to provide either single or redundant dual output signals. This design feature supports steering controls as well as equipment accessory movement.

The H5-S50 joystick by Hydratronics is another typical example of devices supporting J1939 and CANopen. The 3-axis proportional joystick is suitable for the company's CANmaster control system. As standalone unit it comes optionally with a J1939 interface. A common application for the joystick is maneuvering of complex working hydrau- ▶

lics such as cylinder-operated cranes. In addition to the joystick functions, the unit also works as an advanced I/O unit in the CANmaster system, comprising ten digital inputs and two analog input. Two of the digital inputs can also be user defined as either digital output or PWM output. The unit has an internal error log that is automatically transferred to the master units central error log via CAN. The products are designed for cab-environment, nevertheless they are protected against rain and water splash.

The 361G joystick by Elobau provides up to three Hall effect thumbwheel controllers and up to six push buttons switches, including an auxiliary four position analog control installed at the top of the knob. Typical applications may include vehicle controls such as excavators, wheel and backhoe loaders, dozers, skid steer loaders, and other construction, mining and forestry vehicles, as well as agricultural tractors and combines, forklift trucks and other material handling equipment. An optional capacitive presence detection feature is available, and the 361G can be delivered with an integrated CAN(open) interface to reduce the number of wires coming out of the grip. Multiple combination of colors are available for the handle and all integrated controls, and the manufactuer can provide custom made symbols laser printed on the push buttons switches to enable a fully customized solution, based on standard parts.

The Ultratronics joysticks by Eaton provide CANopen as well as J1939 connectivity. The 3-axes devices (Z-dimension is the roller function) feature additional trigger and switch buttons.

For space limited applications, compact devices, so-called “finger” joysticks are used. The MJ-2K series by Metallux comes in IP65-rated housings with a CANopen interface. They feature single-, double-, and triple-axes functionality as those from the competitor Megatron. These TRY12 joysticks are available with a J1939 option; CANopen is not supported. Also Hex Series IV joysticks offered by Apem and CH Products do not support CANopen. The two- or three-axes devices come with J1939 interface and are suitable for heavy-duty vehicles and machinery. Available with several high-function handles and in single, dual or triple axis configurations, HFX Series IV joysticks are custom-configured to meet the exacting requirements of harsh environment applications.

The company Sauer-Danfoss launched the JS6000 joystick series, which supports J1939 and CANopen. There are single- and dual-axes joysticks available. The products do not support the J1939 dynamic addressing, since the joystick source addresses are hard-coded. However, they are compliant the J1939 address claiming protocol (in the unlikely event another node claims an identical source address to the JS6000, the JS6000 may cease communication on the bus, depending on the message priority of the other node). The JS1000 ▶

## J1939 joystick messages

The SAE J1939-71 specification contains two messages dedicated for joysticks. The Basic Joystick Message is transmitted periodically (20 ms). The CAN bit-rate is 250 kbit/s. The content of this message is shown in Table 1. The Extended Joystick Message is also transmitted with a 20-ms period. The signals mapped into this message are shown in Table 2. Compared with the CANopen specification the J1939 is less flexible, but specifies more details regarding the mapped digital inputs. J1939 is also limited to 2-D joysticks, while CANopen also specifies a 3-D joystick.

*Table 1: Basic Joystick Message structure*

| Byte | Bit | Signal name |
|---|---|---|
| 1 | 1 + 2 | Joystick X-axis neutral position status |
| | 3 + 4 | Joystick X-axis lever left negative position status |
| | 5 + 6 | Joystick X-axis lever right positive position status |
| | 7 + 8 | Joystick X-axis position (2 least significant bits) |
| 2 | 1 to 8 | Joystick X-axis position (8 most significant bits) |
| 3 | 1 + 2 | Joystick Y-axis neutral position status |
| | 3 + 4 | Joystick Y-axis lever left negative position status |
| | 5 + 6 | Joystick Y-axis lever right positive position status |
| | 7 + 8 | Joystick Y-axis position (2 least significant bits) |
| 4 | 1 to 8 | Joystick Y-axis position (8 most significant bits) |
| 5 | 1 to 4 | |
| | 5 + 6 | Joystick Y-axis detent position status |
| | 7 + 8 | Joystick X-axis detent position status |
| 6 | 1 to 8 | Grip button 4 to 1 status |
| 7 | 1 to 8 | Grip button 8 to 5 status |
| 8 | 1 to 8 | Grip button 12 to 9 status |

*Table 2: Extended Joystick Message structure*

| Byte | Bit | Signal name |
|---|---|---|
| 1 | 1 + 2 | Grip X-axis neutral position status |
| | 3 + 4 | Grip X-axis lever left negative position status |
| | 5 + 6 | Grip X-axis lever right positive position status |
| | 7 + 8 | Grip X-axis position (2 least significant bits) |
| 2 | 1 to 8 | Grip X-axis position (8 most significant bits) |
| 3 | 1 + 2 | Grip Y-axis neutral position status |
| | 3 + 4 | Grip Y-axis lever left negative position status |
| | 5 + 6 | Grip Y-axis lever right positive position status |
| | 7 + 8 | Grip Y-axis position (2 least significant bits) |
| 4 | 1 to 8 | Grip Y-axis position (8 most significant bits) |
| 5 | 1 to 8 | |
| 6 | 1 to 8 | |
| 7 | 1 to 4 | |
| | 5 + 6 | Grip Y-axis detent position status-not available |
| | 7 + 8 | Grip X-axis detent position status-not available |
| 8 | 1 to 8 | |

joystick family by Sauer-Danfoss comes also with CAN interfaces, supporting CANopen as well as J1939.

Recently, Otto Engineering introduced a product line of joysticks featuring CANopen and J1939 interfaces. The series utilizes a patented Hall effect technology. Electronics are sealed and it has an operational life up to ten million cycles in all directions. Additional options include multiple analog and digital auxiliary control outputs, redundant sensors and a variety of output configurations and a variety of switch options. The CAN interface has been developed jointly with Ixxat. The hardware and the complete joystick software were specified and developed by the system house. In addition to the micro-controller board, an additional I/O board provides the power supply and a variable number of digital and analog I/Os, which enable customer-specific modifications of the joystick handle with additional control elements. Configuration allows the adaptation of the joystick to different system requirements. Standard features include three analog inputs (for three axes) and tewlve digital inputs and two digital outputs. I/O extension for up to 40 digital inputs, eight analog inputs as well as multiple digital outputs is possible.

Penny+Giles offer a broad range of joystick variants in its JC6000 series. The products come optionally equipped with a J1939 interface. CANopen is not yet supported. Also, LOR developed a line of J1939-based joysticks. The devices provide additionally J1939 configurability as well as ten digital outputs, and three analog outputs. The outputs can be used as inputs to micro-controllers or as commands directly to output and valve drivers.

Not only joysticks control off-road vehicles and other mobile machines, sometime also foot pedals are used. In principle, foot pedals are similar to joysticks: one analog input and/or digital inputs. P-Q Controls offers the MCB200 interface module, which can be mounted on the company's joystick or foot pedal. It operates – as required for such applications – in a temperature range from -40 °C to +85 °C. The CAN interface is compliant with J1939. The foot pedals by Otto Engineering are available with J939 or CANopen interfaces.

## Remote joystick

In some applications a wireless connection to the user panel with joystick is needed. In most cases, the wireless link is a point-to-point connection. Increasingly, there is a requirement on safety-related communication on the wireless link. Competition in the radio remote control sector is strong. But the markets are dominated by geographic heroes: Åkerströms, Datek, Tele-Radio, and Scanreco in Sweden; HBC, Hetronic and NBB in Germany; Autec, Imet and Elca in Italy; Ikuzi and Itowa in Spain; Microcontrol/Cavotec in Norway; and Jay in France. And there are some more suppliers, which provide wireless remote joysticks with CAN-connectable receivers.

Cattron's CANopen Mining LHD system is typical example for a wireless user interface with joystick. The system consists of two major components: the OCU (operator control unit), held by the operator, and the MCU (machine control unit), located on the vehicle to control. When connected to a CAN network of the vehicle's main computer or PLC, the MCU acts as a wireless gateway between the vehicle and the OCU. All functions executed on the OCU are transferred on the CAN network. The RF link provides two-way data transmission between the OCU and the MCU. As most ▶

of the remote joysticks, the RF link is proprietary.

Kar-Tech's RF2CAN module is a radio receiver that receives signals from the wireless transmitters with joystick function. The receiver module features CANopen or J1939 connectivity. It's epoxy potted into a small enclosure for easy mounting, and is OEM-configurable for integration into IQAN (by Parker), Plus1 (by Sauer-Danfoss), F(x) (by Eaton) or other programmable machine controllers.

The R170 receiver by Omnex uses a J1939 interface with standardized and proprietary PGNs (parameter group numbers). The device has two CAN ports providing a CAN bridge function. The receiver is configurable regarding the transmitted CAN messages. In proprietary message mode, the J1939 interface (CAN 1) cyclically outputs PDU-2 frames containing the command values from an Omnex transmitter (e.g. joystick). The default transmission period is 10 ms, but this may be changed via the J1939 CAN setup menu.

The TM70 transmitter by Ikusi features multiple "finger" joysticks. It sends the joystick data wireless to the CAN-connectable RCAN receiver, which supports CANopen (CiA 401), J1939, and IQAN. Åkerström is another supplier of wireless remote joysticks, who supports CANopen. In particular in Europe, CANopen is widely used in mobile machinery, so most of the European supplier support this application layer and related profiles such as CiA 401 for joysticks.

In order to standardize the wireless communication, CiA has established the CANopen SIG (Special Interest Group) Wireless Communication. The goal is to develop specifications for bridges, router, and gateways to wireless communication systems including Bluetooth, WLAN, Zigbee, and proprietary radio links. Also the CiA 401 recommended practice for joystick needs to be reviewed and updated, in order to achieve a higher level of interoperability and interchangeability. CiA will also standardize a CANopen interface for driver seats and cabins with embedded joystick functions. (hz)

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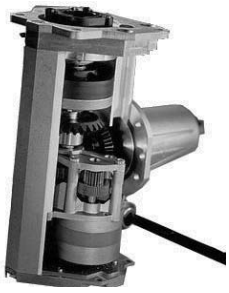
## Actuator for CVT gears



The Smart Aktuator 8960 by Sonceboz was developed for application in CVT (continuously variable transmission) gears of tractors. The device acts as an interface between the electronic gear control and the hydrostatic gear. It translates CAN-commands received from the joystick in the driver-cabin into the angle position values, thus actuating the gear. A redundant control unit and the CAN interface serve for the reliability of the actuator and allow fast on-board diagnostic. (of)

*www.sonceboz.com*

## Valve and digital amplifier

Wandfluh has presented its CANopen-connectable proportional valves and the digital amplifier with four or eight solenoid outputs. The products have been developed in cooperation with Sandvik mining machines. The proportional valves with integrated electronics features SAE J1939 or CANopen connectivity and are compliant to the CiA 408 profile. The MD2 digital amplifier and control electronics comes with CANopen interface and the parameterization takes place through a USB interface by means of the Paso configuration and diagnostics software. This provides some new features: Every channel can be called-up in a window. In doing so, the whole signal flow from the input to the solenoid output with all adjustable and set parameters is evident. (hz)

*www.wandfluh.com*

## Diesel engines with CAN

Yanmar's diesel engines 4TNV88-CR (35,5 kW at 3000 rpm) and 4TNV94HT-CR (88,4 kW at 2500 1/min) extend the company's engine range for exhaust emission-regulated areas. The applied technology includes common rail injection, cooled EGR (exhaust gas recirculation), DOC (diesel oxidation catalyst), DPF (diesel particle filter) and electronic engine governing. Possibility for electronic diagnosis is given via the on-board CAN interface. (of)

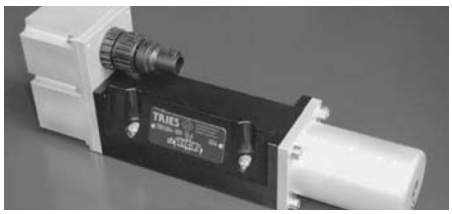
*www.yanmar.com*

## Compact CAN-PLC

As small as a relay (40 mm x 30 mm x 30 mm) is the Micro SPS CAN by MRS. The control unit is graphically programmable, and it provides one analog input, two analog outputs as well as two high-side outputs. The CAN port supports SAE J1939 and CANopen higher-layer protocols. (hz)

*www.mrs-electronic.de*

## Valve control



The 391 series of 4/3-directional control valves by Tries are pilot-operated restrictor valves, which work according to the pressure dividing principle. The pilot actuation is realized by a linear motor. The housing contains electronics for activation and analysis and may be turned by 90°. The valve control is fulfilled via CAN or via an analog signal (±10 and 4 mA to 20 mA). The company's 791 series of multi controller allows integration of conventional proportional valves into a control system, thus enabling diagnose and operation of these valves via CAN. The valves and the IP65-protected multi controller are designed for mobile and industrial applications. (of)

*www.tries.de*

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08.12.2010 Nuremberg (DE)
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