A Programmable Controller for Mobile Machines with CAN-Bus

The importance of electronic controllers for use in mobile machines continues to increase. The industrial demand for more powerful and efficient machines with improved safety and comfort is large, and this, combined with the simultaneous pressure to optimize manufacturing costs, is driving the evolution towards electronic control solutions.

In modern “special purpose” vehicles various systems are automated efficiently with electronic controllers. These include electronic-hydraulic steering systems, hydrostatic vehicle drive regulators with automatic braking system (ABS) or anti-slip regulation (ASR), engine management (speed regulation), transmission/gear control, and complete task specific hydraulic control of a mobile machine (earth moving equipment, construction equipment, service vehicles, public utilities vehicles, etc.).

An important consideration in many applications is the interaction between the electronic controller and hydraulic valves. Equipment manufacturers, using modern micro controller technology and regulation algorithms with a high dynamic response, achieve very sensitive control of hydraulic valves. Thus vehicles and loads weighing many tons can be moved and positioned with millimeter accuracy!

Due to the fact that mobile equipment frequently works in harsh environments, electronic controllers for mobile applications are required to operate in an extended temperature range (automotive: −40 ..+85 °C/-40°F…+185°F), and be durably housed. The controllers must also have high immunity to electromagnetic disturbances (EMC), be protected against voltage overload and external short-circuits, and have imbedded diagnostic capability for the I/Os.

Another important aspect, arising from the increasing complexity of modern equipment, is the need for economical communication between the individual control modules on a serial data bus. This provides the complete system with the advantages of a modular, decentralized structure. Sensors and controllers exchange data digitally, with signals continuously available to all participants at the same accuracy. Operator panels, sensors, actuators and controllers can now be optimally located with a fraction of the original wiring (lowering production costs and increasing operator comfort).

With serial communication, the system can later be extended easily and allow different control circuits (e.g. vehicle control, comfort electronics or navigation system) to exchange commonly required data. The serial interface also provides a simple access point for programming or configuring the system, for setting system parameters, for visualizing system or process conditions, for diagnosis, for error evaluation and for service or remote maintenance work (i.e., new calibration over modem).

CAN-Bus

The "Controller Area Network" (CAN), originally developed by Bosch for use in the automotive industry, has established itself as the standard bus system for mobile applications (international norm ISO 11898). Components for CAN-based systems are available in large quantities at very reasonable prices due to their wide spread use.

CAN-Bus systems exhibit high transfer rates (CAN low-speed up to 125 Kbit/s, CAN high-speed to 1Mbit/s) and high data transmission reliability. A number of different capabilities (CRC, frame checking, acknowledgment, bit monitoring and bit stuffing) enable the CAN protocol to recognize errors in transmitted data, caused for example by electromagnetic disturbances, and to correct them (transmission stop with error flag and automatic repetition of the message). Since the length of the data packages are limited to max. 8 bytes of information per message, correction takes place with very little loss of time.

A pair of wires suffices as the transmission medium (ease of wiring). The length of the network can be up to 40 m with transfer rates of 1Mbit/s. Networks without repeaters up to 1000 m in length are practical with rates up to 80 Kbit/s or less. The number of participants per network (in theory unlimited) depends on the type of chip used (transceiver or physical layer). With commonly used chips, 32, 64 or up to 110 (with restrictions up to 128) nodes per network are possible (further extensions require repeaters or bridges).
CAN is a "multimaster system" with line topology and real time capability. Unique “identifiers” contain information not directly related to the address of a participant, but to the contents of a message (i.e. temperature, rotational or linear speeds). All participants check out the identifier being transmitted and decide if the type of message is relevant to their function (acceptance filtering). In this way all messages can be received from many or all of the participants simultaneously. The unique identifier also determines the priority of the message relating to bus access. In case a number of participants try to access the bus simultaneously, the higher priority message is guaranteed to gain bus access (prevention of bus accessing conflicts is done through bit wise arbitration). For these reasons it is important to incorporate functional procedures and safety requirements into the process of defining identifiers. Standard format (11-bit identifier) and extended format (29-bit identifier) are two different message formats that can coexist on the same physical CAN-Bus. The specification CAN 2.0 B supports both formats, while CAN 2.0 A only allows frames with 11-bit identifiers.

Through content oriented identifiers in a message, the system achieves a high degree of configuration flexibility and allows a simple extension of the network to include further devices. There are a number of higher protocols such as SAE J 1939, OSEK, CAL (CAN Application Layer, the basis for the communications profile CANopen), DeviceNet, ISO 11783 or LBS (Tractors and machinery for agriculture and forestry — Serial control and communications) and others that have been standardized. These are available on the so called ”application layer”.

The various semiconductor manufacturers offer CAN controllers with differing functionalities: one common type has one data buffer for transmitting and one for receiving - here the receive buffer is followed by a shadow buffer and the message filtering function utilizes the associated microprocessor ("Basic-CAN"). Another type has a number of buffers for managing and filtering multiple messages simultaneously ("Full CAN", reduces workload on CPU). In addition there are so called SLIO (serial linked I/O) devices, which require no further microprocessor but function only as CAN slave modules (for I/O extension).

**Electronic Controller and Drive Unit ESX**

Based on the efficient Infineon C167 16-bit processor (Siemens), Sensor-Technik Wiedemann GmbH has developed the ESX, a programmable controller unit for complex, dynamic control of mobile equipment and vehicles. Particularly suited for vehicles in rough environments, and at extreme operating temperatures (-40...+85 °C/-40°F…+185°F), the ESX offers a large number of short circuit protected diagnosable digital and analog I/Os, RPM inputs, and pulse width modulated outputs. The ESX is an independent unit, equipped with all the measurement, regulation and driving electronics required for sensor actuator management, and capable of simultaneously executing multiple independent or linked tasks in real time.

Proportional valves can be driven directly with PWM outputs with internal current measurement without additional expensive amplifier and/or driver boards. Alternatively (for valves with integrated electronics) valves may be driven directly from the 1 to 5 Vdc outputs.

A durable, cast aluminum die housing (protective grade IP 65, opt. IP 67) provides both high immunity to electromagnetic disturbances and high longevity under extensive mechanical stressing.

**Photo: Controller ESX with CAN-Bus fulfills the requirements for "AK 4", "category 3" and "SIL 2" for safety-relevant applications**
The ESX controller has two internal slots for extension modules, which can extend its capability with up to 12 additional inputs and outputs. These inputs and outputs may be freely combined, so that the ESX can be adapted and/or expanded for customized requirements at any time.

Beyond being certified to CE standards, the ESX fulfills requirements and standards of the construction equipment, agricultural machinery and automotive industries. The ESX is also designed for safety relevant applications to meet the safety grade “AK 4”. Principles for computers in systems with safety-tasks in DIN V VDE 0801, “category 3”, Safety of machinery – Safety-related parts of control systems in EN 954-1 and “SIL 2”, Functional safety of electrical/electronic/programmable electronic safety-related systems” is introduced as IEC 61508.

Some features of the ESX are:

- All input and output channels of the controller are diagnosable, i.e. the software can determine whether a short circuit or an open load is present.
- The internal hardware continually monitors itself, and provides diagnosis using software checks.
- A safety switch-off relay serves as secondary switch-off method.

Data exchange with other intelligent units is made possible with an RS 232 serial interface and a CAN-Bus interface according to CAN specification 2.0 B (Full CAN, 15 message object registers) that supports both the standard and the extended format. A number of controllers can thus be networked with the CAN-Bus. Over and above this, an extension module is available for the ESX providing additional independent CAN bus interfaces. This allows the ESX to function as a bridge between independent bus systems. The transceiver chip which implements the physical connection (physical layer) to the bus, PCA82C251 (Philips), conforms to ISO 11898 - 24 V (short circuit proof, for use in 24 V systems) and transmits data at rates up to 1 Mbit/s. Characteristics, parameters, and calibration data for the sensor-actuator management can be stored in non-volatile memory (EEPROM). The controller retrieves this data at system power up.
Software programming is done either in the high-level language "C" or using an IEC 1131-3 interface with the following programming languages:

- Function Block Diagram (FBD)
- Ladder Diagram (LD)
- Instruction List (IL)
- Structured Text (ST)
- Sequential Function Chart (SFC)

Software download into the Flash memory is performed with one of the CAN or RS 232 interfaces. For customers who wish to program and configure the ESX themselves STW makes extensive function libraries available as well as programming and diagnostic tools. STW can also develop a complete customer software solution.

**Application Example:**

Electronic-hydraulic steering provides the freedom to individually align vehicle axles and components as desired. The steering functions dynamically adjust for the instantaneous vehicle speed and steering angle. An automatic guidance system (e.g. inductive, optical, ultrasonic or with navigation or traffic control systems) relieves the drivers of excess workload and lead to quicker handling times. Accidents and sheet metal damage are reduced or avoided.

With fewer hydraulic components (steering actuator valves are set electronically), as well as less tubing and connectors, production costs are lowered. The ESX electronic control system provides the highly dynamic regulator functions (with electronic load sensing) required for these electronic-hydraulic steering systems.

**Reference publications on CAN:**

2. Prof. Dr.-Ing. Konrad Etschberger, CAN, Controller Area Network, Hanser Verlag, 1994
3. Prof. Dr. Wolfhard Lawrenz, CAN, Controller Area Network, Hüthig Verlag, 2. Auflage 1997