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MOBILE MACHINES MECHATRONIC SYSTEMS AND SOFTWARE

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Abstract

Use of specialized computer components is essential for automating work of mobile machines. All the control and management of mobile machines is based on special sensors and actuators as well as on specific highest programmable units that are significantly different from the conventional controllers and PLC systems. This paper gives a brief overview of the most important mechatronic systems, and their corresponding programming support, used for mobile machines with special reference to analysis of work of their respective components.

Key words*: mobile machines, sensors PLC systems,*

1 INTRODUCTION

Today management of modern mobile machines use mechatronic systems which built around microcontrollers and the electronic components such as sensors, potentiometers and the hydrostatic components with regulators of diesel engines, hydro-pumps, hydro-motors and actuators of drive system machine.
The mechatronic system management functions by state signals, collected by sensors, and operator command signals, transmitted over the potentiometers, make the input signals the microcontroller. Microcontroller analog input signals are first converted to digital and then is processed the software.
To obtain useful analog signals with appropriate characteristics for driving components of the system of machine: diesel engine, hydro-pumps and actuators processed digital signals are again converted back into analog. Microcontroller is usually connected to the display to monitor the parameters system state and with external devices: control desk or computer with software for diagnostics and parameter setting of the system. Communication signals of mechatronic systems are realized by CAN bus (Controller Area Network) bus) (Fig.1).

2. COMPONENTS OF MECHATRONIC SYSTEMS

2.1. Sensors

The sensors register the physical size the system state and convert them into the corresponding analog signals. Depending on the nature of the physical size which are registered sensors (encoders) : walking, movement (length), angle, angular velocity (RPM), force etc.
Control actuators is often not a linear process. Control valves are resistive devices, similar to an electrical resistor, where the flow (current) is a function of the pressure drop (potential drop) across the device. The result is a flow proportional to the supply pressure (Ps) minus the load pressure (Pl), and because of that flow for a given valve command will vary as the load and supply pressures vary. As many hydraulic control valves do not have a linear flow vs. signal characteristics the result is a control loop gain that can vary widely. Nonlinear gain usually results in poor performance or instability.
Because of that control is a compromise between accuracy and stability. Controller must be able to compensate for these non-linear characteristics so that gain, and accuracy and response, can be optimized. Advanced controllers have the ability to compensate or linearize characteristics to improve system performance. Additional control capabilities also monitor load forces or pressures and adaptively adjust the controller gain to maximize performance.

Fig. 1. *Components of mechatronics system*

2.2. Microprocesors

Using microcontrollers in industrial production machinery requires high performance, high accuracy and flexible configuration capability. Conventional PLCs and PID controllers used by many end-users today do not provide specialized control features needed for high-performance sensors and drives. Required controllers designed and optimized with these features, must allow the full range of features and performance to be realized. If the control valve or control electronics are too slow for the desired application, the result can be poor control performance. The resulting issues that occur are overshoot and undershoot of pressure, pressure instability, and the inability to reach the desired accuracy. Poor throughput (throughput = PLC scan time + analog input conversion time + analog output conversion time) can result in update rates taking as long

as tens of milliseconds, which can allow the pressure to exceed the desired set point before the next output value is generated, resulting in over/undershoot or instability.
Using a controller that is designed for control applications can eliminate these problems. High throughput speeds, combined with control algorithms that go beyond conventional proportional-integral-derivative (PID) control loops, can directly or predicatively control pressure and force under the most extreme performance demands and provide accurate, stable pressure and force control. For use in mobile machines were developed special microcontrollers with case that meets the requirements of protection in terms of temperature, hermeticity, resistance to shock and vibration, and electromagnetic interference. Microcontrollers powered sensors and potentiometers with input voltage and from them receive analog signals in the form of voltage range of 0 to 5 V. Same of wanted features are:

- High performance
- Robust design meeting specifications for mobile
- applications
- High electromagnetic compatibility (EMC)
- Inputs and outputs with fault detection
- Central deactivation of all outputs
- Pulse-width-modulated (PWM) solenoid currents for minimum hysteresis
- Closed-loop control of solenoid currents, i.e., not dependent on voltage and temperature

Usual main components:

- Watchdog processor for program run monitoring
- Hardware-based RAM memory supervision
- CPU-internal Flash with ECC error-correcting code
- Three independent sensor power supplies
- Four independent CAN bus interfaces
- Two-channel stop function

In according with these requirements, there are numberous microcontrollers available in the market and tipical represent are BODAS controllers RC series, universal central control units for complex mobile working machines. They have 32 bit TriCore built in processors, clock frequency of 180 MHz and parallel processing.
There are programmable control of proportional solenoids and additional switching functions to travel drives and transmission control as well as coordination of complex control circuits in mobile working machines. These control units provide 75 input channels, up to 42 output stages, four voltage outputs, an additional analog output (4 to 20 mA) as well as four CAN buses for communication in the vehicle, as a platform for all functions of mobile working machines.
Analog voltages is in the range from 0 to 10 V and 0 to 32 V, currents from 0 to 20 mA, frequencies from 0 to 10 kHz and switching information are processed as input signals. In addition, these control units offer special inputs for intelligent Bosch Rexroth sensors, such as the DSM1-10 speed sensor with integrated diagnostics function or resistor inputs from 10 to 2000 Ω, for example for the direct connection of temperature sensors. Same interfaces of inputs with sensors are shown in the *Fig.3* and *Fig.4.* The inputs are protected against overvoltage and electrical interference. The voltage inputs can be monitored to detect any cable breaks or short circuits. The current-controlled proportional solenoid outputs are pulse-width-modulated (PWM) and are compensated for fluctuating temperature and voltage for high accuracy and minimum hysteresis. The switching outputs are designed for direct switching of relays and switching solenoids.
CAN-bus interfaces are included in all BODAS RC controllers for exchanging data with other bus users or electronic systems (e.g. RC, joystick, diesel engine injection, display). Each of the four independent CAN bus interfaces can be operated using different protocols.
Communication with the BODAS-design and BODAS-

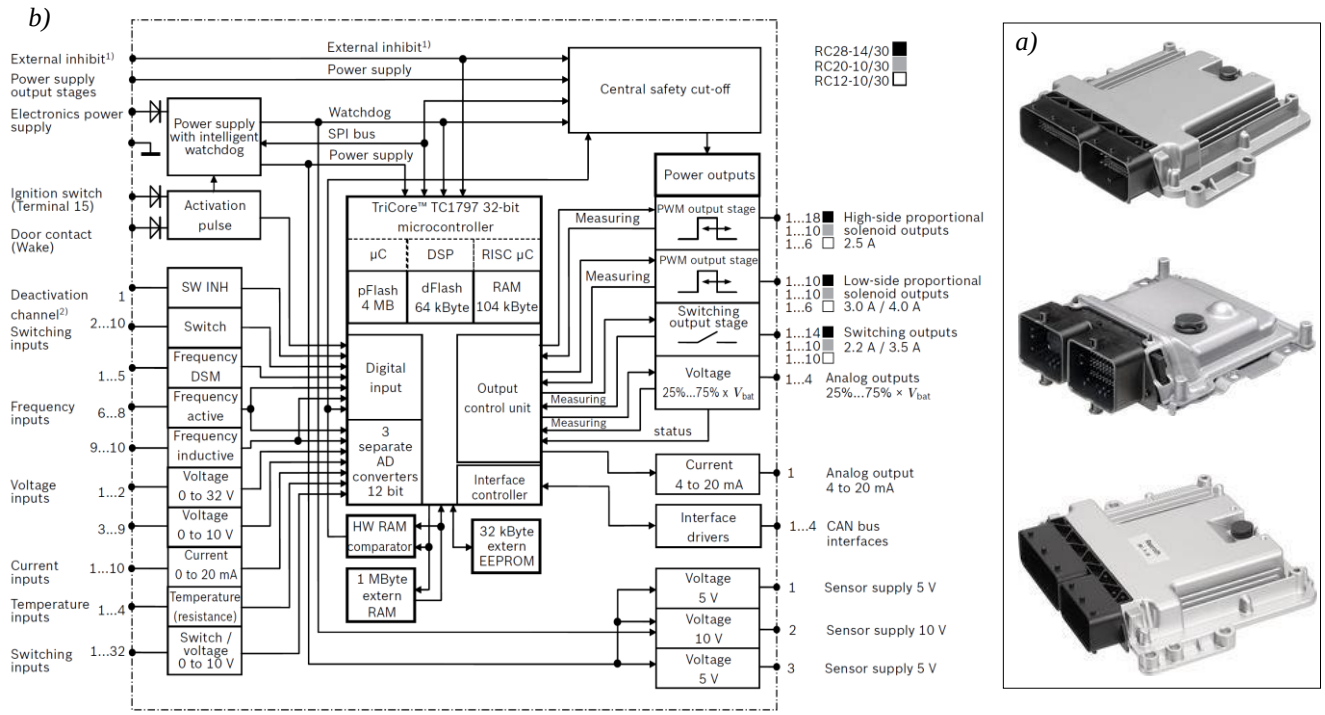

Fig. 2. *BODAS controllers: a) internal organisation, b) BODAS controller RC series [1]*

service software is done via CAN bus and is based on the Standard Key Word Protocol 2000 (KWP 2000). Manufacturers often control systems use specialized processors from other manufacturers as the core around which to build own application and develop own software. Usually manufacturers of controllers offer its software and complete solutions.

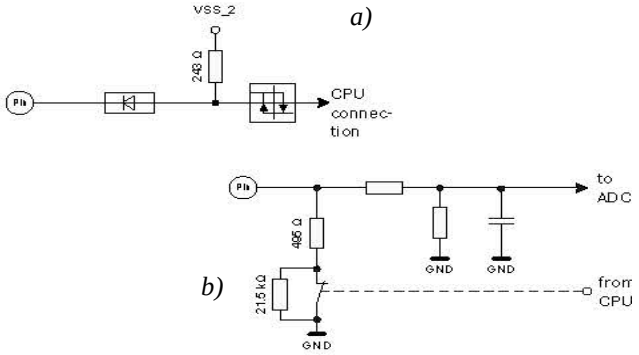

Fig. 3. *a) analog current input with switchable internal ohmic resistance, b) frequency input for Type NPN active sensors*

2.3. Sofware

Software design is the process of implementing software solutions to one or more sets of problems. Software design may be depending upon the availability of the technology used for the design. One of the main components of software design is the product development cycle from design, simulation, creating the application software, right through to commissioning and series production, as shown in the figures *Fig.6.* to *Fig.7.*

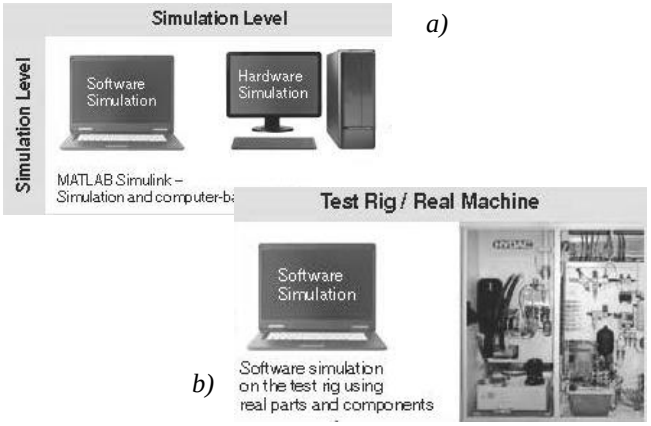

Fig. 4. *Simulation in real conditions:a) step 1, b), step 2*

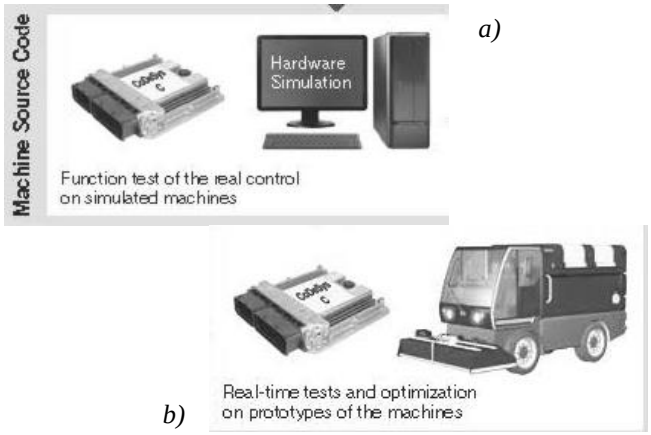

Fig. 5. *Functional testing and optimizaton: step 3, step 4*

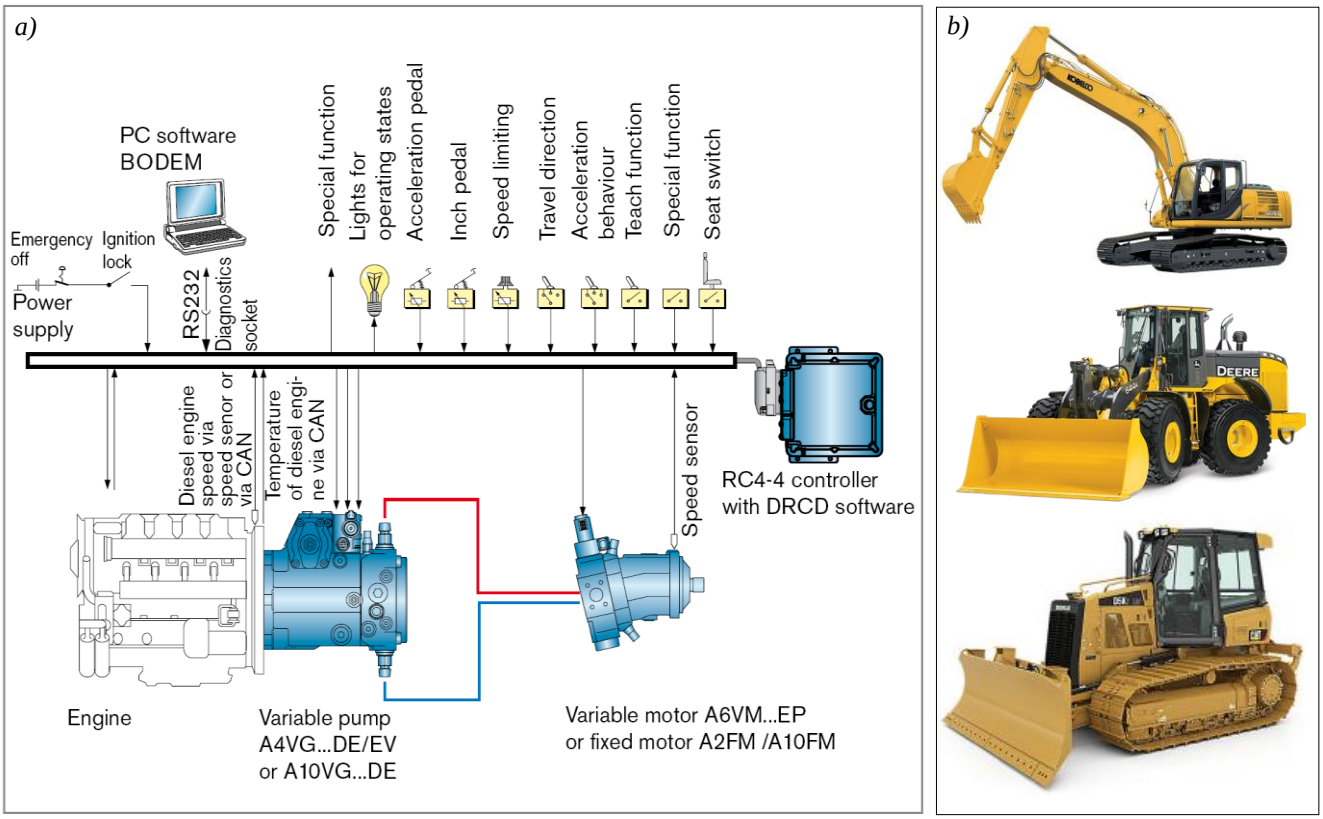

Fig. 6. *a) Typical configuration for the SPCC for an open hydraulic circuit [1], b) Mobile machines with open hydraulic circuit*

Because of the prevalence and good knowledge development tools are usually C, C++ and MATLAB / Simulink. All controller manufacturers offer suitable libraries with Windows PC interface.

From setting up the hardware, to sequencing the machine processes, to controlling and integrating the controllers, the use of software and hardware components that utilizes standard, off-the-shelf hardware and software products are needed. As an example for integrated user interface and diagnostic and maintenance function, we consider Rexroth's BODAS-service that provides access to all parameters and process variables to the user in a clear manner for easy editing.. Any errors detected in the electronic system by the controller are communicated by the BODAS-service diagnostic function in plain text so malfunctions easily can be recognized. The software can be used to graphically display process variables, both instantaneously and as a function of time. The software permits the recording of data with a data logger.

In addition, Bosch-Rexroth provides their own proprietary Windows-based software (BODAC).

The software (which can be obtained directly from Bosch-Rexroth Industrial Hydraulics Division) has the following functionality: setup, troubleshooting, upload and download parameters, tuning, parameter monitoring, real time graphing, and module diagnostics.

Work with the diagnostic function is further simplified by the "System Scan." This feature queries all controllers connected to the diagnostic computer via CAN bus and RS232, displays them on the screen and provides an overview. As a result, multiple controllers can be detected and diagnosed simultaneously without having to plug them in one after the other.

When using the software with Rexroth controllers the software also displays extensive version information. In addition emergency access is also possible; Rexroth-service can enable full access to all process variables and parameters for a one-time connection.

The diagnostic module information requires no programming knowledge.

Very usefull function is the configurator. When creating software either with BODAS-design or the C programming language — the configurator is used to create the setup and diagnostic configuration. This defines which parameters, process variables and error messages are displayed and can be changed later with the BODAS-service diagnostic function, along with the ability to provide authorization or lock-out levels for viewing, engineering or service.

Software can be loaded or updated on a BODAS controller using the flash function integrated in BODAS-service. Inclusion of this tool is new features, increasing the ease of use for the user.

Communication based on international standards

The BODAS-service diagnostic function is based on the RS232 standard and the standard CAN diagnostics architecture defined by the ASAM (Association for Standardization of Automation- and Measuring Systems). Thus, the software is compatible with all BODAS controllers from Rexroth. Depending on the device generation, configuration is performed via an RS232 or CAN interface.

Data exchange is based on ODX in accordance with ASAM. This formal descriptive standard defines the protocol formats for exchanging data for vehicle or controller diagnostics. For communication, the software uses UDS and KWP 2000. These are two internationally standardized communication protocols used in automotive electronics (Unified Diagnostic Services and Key Word Protocol). Using such a type of programming ensures compatibility with current and future controller generations. Typicall full hardware and software application is shown in *Fig. 5* and *Fig. 6.*

The electronic speed control, variant C (SPCC) is an easily configurable software application for the open and closed loop control of hydraulic drives.

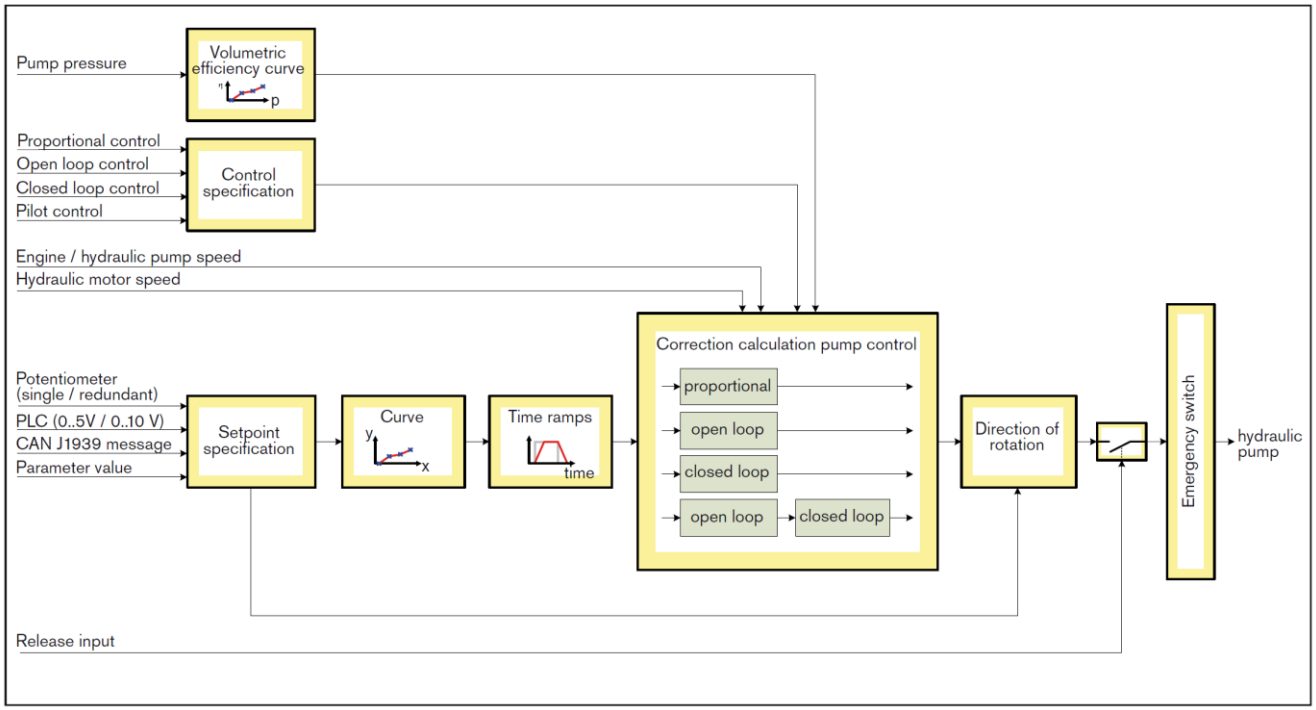

Fig. 7. *Operation principle of speed control SPCC [1]*

The hydraulic drive consists of a pump and a motor. The speed control serves to keep the drive speed constant, independent of the speeds of the diesel engine and the hydraulic pump.
The SPCC electronic speed control is designed to control a Variable pump in a closed or open hydraulic circuit.
The following hydraulic concept is used in an open hydraulic circuit:
– A variable pump A11VO, A7VO or A17VO with electro proportional control EP together with fixed motors A2FM, A2FE, A4FM, A10FM or MCR
In a closed hydraulic circuit, the following hydraulic concept is used:

– A variable pump A4VG or A10VG with electroproportional control EP together with fixed motors A2FM, A2FE, A4FM, A10FM or MCR. For an open loop control either diesel engine speed or pump speed needs to be measured. For realization of an open loop control two different designs of diesel engine can be used.

3. CONCLUSION

All types of mobile machines have mechatronic management systems, which, according to the requirements, use specialized computer components provided by worldwide manufacturers that are significantly different from the conventional controllers and PLC systems. Those systems with appropriate software enables mobile machines synchronized movement and manipulation, ecological and economical operation of the drive system, complete monitoring and full comfort of the operator.

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