Assembly and testing line for steering booster motors

EtherCAT enhances test rig automation

Vogelsang & Benning are specialists in fully- and/or semi-automated end-of-line testing for industrial production. Since the company was founded in 1983 it has produced test systems for a huge range of industrial applications, implementing drive technology and mechanical engineering. For the latest assembly and testing line developed for steering booster motors, Vogelsang & Benning have chosen a PC- and EtherCAT-based automation solution from Beckhoff.

Complete assembly line

Power supply test specimen
(serial communication)

Frequency converter: load test specimen
(PROFIBUS)

Joining spindle + screwdriver (PROFIBUS)
Scanner, ECU (serial communication)

Linear unit (PROFIBUS)
Scanner, flash unit (serial communication)

Flexray gateway (Ethernet TCP/IP)
Tightness test (serial communication)

Measured value recording
with distributed clocks
Flexray gateway (Ethernet TCP/IP)

Fig. 1: Flexible topology, great interface variety

Increasingly, conventional hydraulically-assisted car steering systems are being replaced by electro-mechanical units. The overall servo unit (SU) consists of a permanently excited synchronous motor and the electronic control unit (ECU). The motor itself undergoes comprehensive testing before leaving the supplier. The overall assembly and testing line consists of a screw and flash module and a tightness and performance testing module with integrated handling modules. The ECU and the motor are joined and screwed together in the screw module and the application software is transferred (flashed) to the ECU in the flash module. This is followed by the tightness test and the performance and noise test. Since the steering obviously represents a critical safety component in the vehicle, particular attention is paid to the data backup and archiving. All test parameters, settings and measured data must be traceable. Each test specimen must be uniquely identifiable and saved to a separate, central file server.

The test rig automation requires integration of components from a wide range of manufacturers with a wide range of interfaces: the test module load set has a PROFIBUS interface. The specimen's control unit is actuated via FlexRay while the FlexRay gateway is actuated via Ethernet. Additional equipment such as scanners, flash units or the tightness tester communicate with the control computer via serial interface.
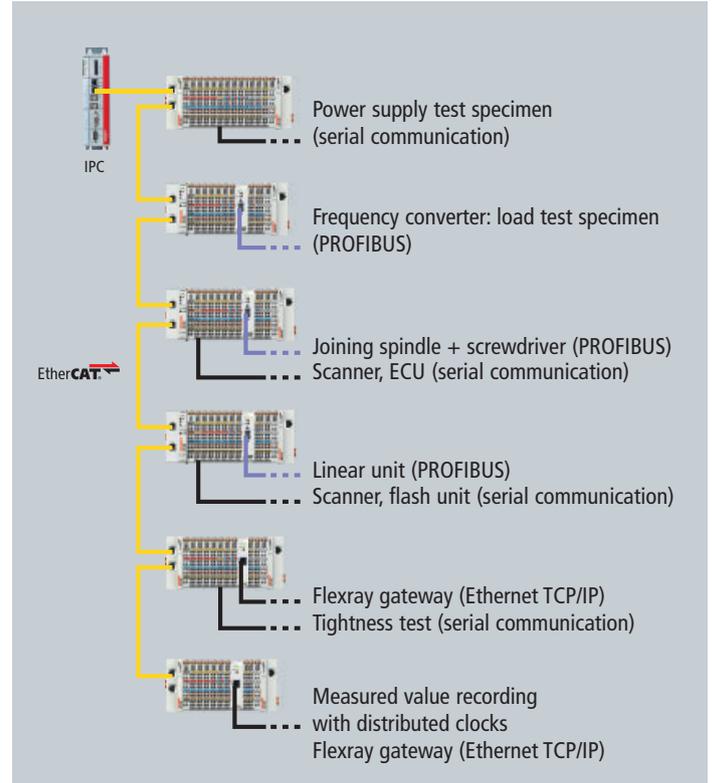
EtherCAT as higher-level bus system

One of the main reasons for the selection of EtherCAT as the basic bus system, apart from its high performance and precise distributed clock-based synchronization of process values, was the availability of the aforementioned interfaces as locally distributed EtherCAT devices. Furthermore, a substantial requirement of the end customer was to have the ability to add additional modules as unit quantities increased by expanding the bus. By decentralizing the cited interfaces (see fig. 1), this requirement can be fulfilled without excessive wiring and installation costs. Where the use of multi-channel interface cards used to require the laying of several meters of serial cable, now the routes are short and the susceptibility to interference is greatly reduced.

The test modules detect the key characteristics of the steering booster motor:

| tightness of the screw-fastened components to one another
| various load tests with torque and speed checks
| noise tests under different operating conditions
| verification of all parameters and of the overall ECU function

Standard EtherCAT Terminals record measured values

The specimen is assigned a default torque via FlexRay which must be maintained very precisely even under loads (convertor-controlled load machine). The torque is constantly measured at a constant speed at a sampling rate of 1000 measured values per second. The torque discrepancies are analyzed with the help of a fast Fourier transform (FFT). To ensure that this provides reliable analyses, the measured data (torques) must be recorded in absolute temporal and/or angular synchronization. Whereas this measured value recording once required expensive, special instrumentation, it can be carried out today using standard EtherCAT Terminals (counter terminal and analog input) with distributed clock function. The distributed clocks enable the measurements to be synchronized with nanosecond-precision, thereby providing the necessary temporal correlation of the measured data for the FFT. Torque discrepancies are then graphically displayed in the frequency-amplitude spectrum. The test result is stored in the database together with the DMC code.

The performance capability of the EtherCAT system with distributed clocks is clearly shown in fig. 2. Two EtherCAT-synchronized edge changes have been recorded. The two units are separated by 300 EtherCAT nodes and 120 m of cable. The simultaneity of the synchronously controlled edge changes was approx. 15 nanoseconds (ns) with jitter of ±20 ns.
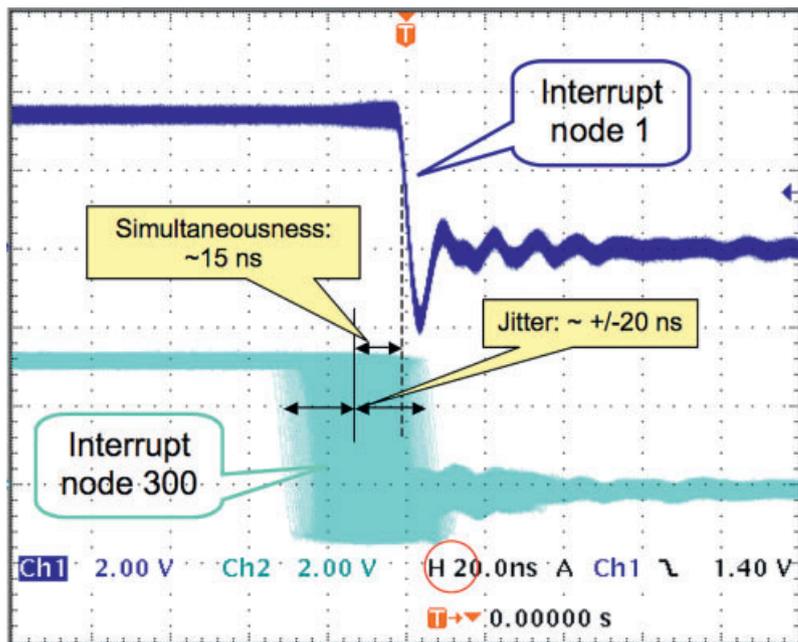
Assembly and test flow in detail

In the first stage, the motor and control unit are joined and screwed together. Joining spindle and screwdriver are controlled via PROFIBUS. A scanner with a serial interface detects the specimen's DMC code for the necessary material tracking and archiving in the database. In the next stage the firmware is loaded onto the ECU via flash module – also serial – while the handling system (PROFIBUS) transfers it to the next module. Material tracking is carried out via a serial scanner. This stage incorporates an EtherCAT switch port terminal to carry out direct settings on the ECU via an optional FlexRay gateway. The connection with the gateway then takes place as pure TCP/IP communication within the acyclical communication slots of the EtherCAT system.

Fig. 2: Nanosecond precision and synchronization with distributed clocks; long-term recording of two devices

ADS permits the transfer of complete measured data records within a few milliseconds

The measured and calibration values are analyzed and visualized and the test results archived with the METIS software programmed in C++ which was developed and implemented by Vogelsang & Benning. The interface for the TwinCAT controller is ADS, a convenient router interface for data transmission, control and diagnostics. The excellent integration and convenient command interface (e.g. for switching operating modes) make communication much easier and more effective than the previous handling of data modules in the PLC. Complete measured data records are transferred to the METIS software in a few milliseconds by the PLC. ADS is embedded in the TCP/IP protocol for remote maintenance. The necessary settings in the METIS software are minimal.

A pioneering solution

"I hope we can convince many customers to fit test rigs with Beckhoff technology," says Robert Biletic, project manager and programmer of the test line described above. "It has given us substantial benefits over the solutions we used in the past. These are, firstly, the aforementioned de-centralized fieldbus interfaces (EtherCAT devices), which enable a highly flexible topology and device selection. In addition, PLC-programming has become more efficient and more cost effective thanks to the availability of high-level languages (structured text; ST) and the instance concept, plus the reusability of software modules. The TwinCAT System Manager and an integrated real-time scope offer excellent diagnostic options. The integrated online visualization makes it easier to find and remedy wiring errors quickly and easily, even without a PLC program, just with the System Manager. The scope is also useful for the adjustment and optimization of a wide range of controllers. EtherCAT is an extremely effective fieldbus system and allows us to use standard I/O terminals as the recording level for high-precision measured values. This not only saves money, it also means the entire measurement operation can be resolved in software. The knowledge remains with us in-house and we can carry out simple adaptations to other test rig applications."

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