CiA 402 not only for operation, but also for device testing

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The company is the successor of Gefeg founded in 1948 and Neckar Kleinstmotoren founded in 1967. The latter produced compact brushless DC (BLDC) motors with integrated electronic motor control since 1995. In 2005, the merged companies started the development of an electronic platform with the capability of communication. Feedback from customers showed that CANopen was a good choice for a high-performance but cost-effective bus solutions.

Links
www.gefeg-neckar.de
www.microchip.com

Figure 1: Brushless DC motor with integrated CANopen interface (MC 663)

The first application of our motion control platform was a compact BLDC (brushless DC) drive. These motors have long service life as a result of the brushless technique. The high-quality rare-earth magnets enable high efficiency, and the compact, closed construction guarantees a high environmental protecting class. The motors can be combined, similar to all motors of this manufacturer, with worm, spur and planetary gears, with brakes and with shaft encoders.

The control algorithms are implemented in the dsPIC33F digital signal processor (DSP) by Microchip. Three Hall sensors detect the rotor position, which serves for proper electronic commutation of the brushless motor. Additionally, the Hall sensors are used for speed measurement and for speed control. The 24-V power module is based on SMD-MOSFET transistors. They are soldered on a PCB from aluminum enabling proper cooling.

The integrated CAN interface is compliant to the CiA 402 CANopen profile for drives and motion controllers. This makes testing easy and enables direct parameter settings. The firmware also includes a boot-loader, which allows firmware updates via the CANopen interface.

The MQ 667 brushless motor with a 68-mm diameter features an optimized magnet circuit and an improved winding technology. In comparison to its ancestor with the same diameter (M 663), axial length is decreased by 15 %, torque is increased by 60 % and cogging torque is reduced considerably.

The PMDC (permanent magnet DC) motor uses the same electronic platform. In spite of mechanical commutation, these drives also contain Hall sensors for the position detection. These sensors deliver speed information for the closed-loop speed control.

By integrating all components such as power unit, motor control unit, measurement system and bus interface, wiring and planning effort is reduced to a minimum. Only the supply cable and the bus cable remain. Therefore, the overall availability increases. Furthermore, the space required in the electronics cabinet is reduced. Nevertheless, there are applications where the integrated solution is not preferable. The reason can be that environmental temperature is too high or that installation space is strongly limited. To cover such applications, an external control unit with CAN interface has been developed. This control unit is based on the same hardware and firmware as used in the integrated solutions. This ▷

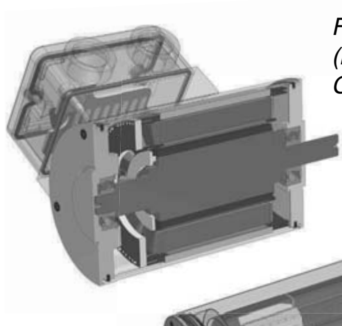


Figure 2: BLDC motor (MQ 667) with integrated CAN interface

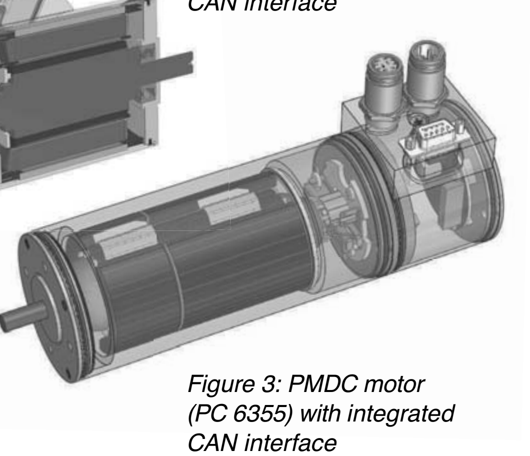


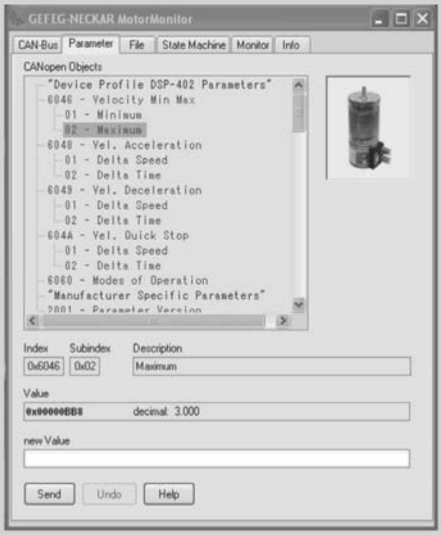
Figure 3: PMDC motor (PC 6355) with integrated CAN interface

Figure 4: External CAN interface unit for BLDC and PMDC motors

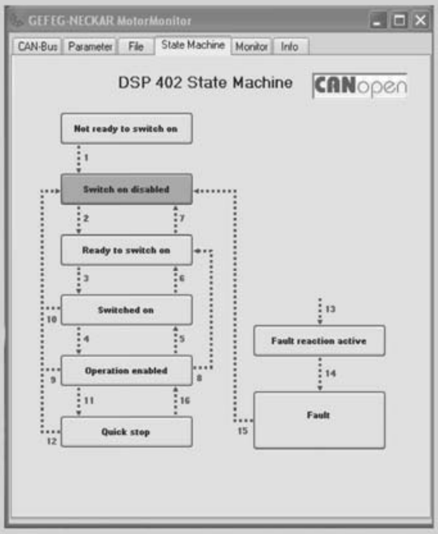
allows controlling stand-alone PMDC and BLDC motors in the same way.

Drive commissioning software

For commissioning, parameter setting, manual testing and monitoring the motors with integrated electronics, the "MotorMonitor" software for Windows computers has been developed. The software is written in the C++ programming language. It needs a CAN/USB adapter to communicate with the motor using the CANopen communication services. At first, the PC software establishes the communication with the motor. After that, it requests the firmware version of the drive. The software contains a database with all released firmware versions. Therefore, only the parameters implemented in the actual motor are displayed. The software tool allows the user to change parameters, control the drive or monitor important data such as rotor position, velocity, power consumption, and temperature. The company grants rights of use of this software to its customers free-of-charge. However, customers cannot change certain safety-relevant parameters.



Graphical user interface of the "MotorMonitor" commissioning software ("Parameters" tab card)



"State Machine" tab card of the commissioning software

Electronically commutated motors for 230-V_{AC} mains

At safety low-voltage drives, the AC mains voltage has to be converted in two steps. A switch-mode AC/DC converter generates a safety-low voltage (e.g. 24 V_{DC}) from the 230 V_{AC} (50 Hz). From this DC voltage, the commutation unit generates a three-phase AC voltage system with variable amplitude and frequency for the motor windings.

Using a commutation unit for direct mains operation, investment spending, system complexity and power dissipation can be reduced. For this reason, such commutation electronics were developed based on an intelligent power module. In comparison to a safety low-voltage DC unit, additional functional blocks have to be integrated:

- Single phase bridge rectifier
- DC link capacitor
- Initial current limiter
- EMC filter
- Switched mode DC/DC converter for the internal control electronics
- Safe potential separation between power circuits and bus signals

The difficulty of this task is the design of a compact unit while fulfilling the statutory low-voltage directive and EMC regulations. An additional problem is how to resolve effective cooling in order to guarantee a reliable operation of the power and control electronics and to ensure a sufficient life span of the temperature-sensitive electrolytic DC link capacitors. By integrating this electronic unit in a motor with permanent magnet rotor, an electronically commutated (EC) motor with integrated CAN interface for 230-V_{AC} supply has been developed.

Induction motors with CANopen

Induction motors have a lower nominal torque and a lower level of efficiency than electronically commutated motors do. However, induction motors do not need expensive rare-earth magnets for their production. For speed variable drives, a converter can supply the induction motor with variable frequency.

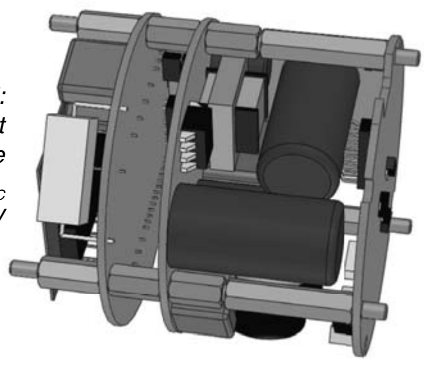
With a modified firmware, the commutation unit of the EC motor can act as a frequency converter for three-phase induction motors. By integrating this unit into the motor housing, a compact variable speed induction drive can be achieved.

Benefits of this drive are CANopen interface and closed-loop speed control, similar to those of all the other members of the large family of drives with the same electronic platform.

Automatic inspection system

The integrated CAN interface also enables an easy, cost effective but detailed ▷

Figure 5: Commutation unit with CAN interface for direct 230-V_{AC} (50 Hz) supply



Abstract

This article describes the development of a family of sub-fractional horse-power electric motors with integrated CANopen interface. The integration of motor and control unit with CANopen allows an automatic final test in the motor production line without the need of test stands.

DC motor benefits

Due to inexpensive magnet systems (sintered ferrite segments) and automatic production lines, DC motors are cost effective. On the other side, the life expectancy of these motors is limited by the commutation system consisting of collector and graphite brushes. However, there are numerous applications where the necessary active service hours do not exceed the maximum limit, in the majority of cases 3000 hours. In such applications, a conventional DC motor with integrated speed control and bus interface might prove to be an interesting and cost effective alternative.

test of these motors in the production line. For the final test, a test system has been developed. It utilizes the CANopen protocol to communicate with the integrated electronic platform (CiA 402). The test program is based on the routines of the commissioning software. Without requiring any expensive test station, it is now possible to test the drives automatically. There is no need for any additional sensors for testing, because the integrated intelligent control unit contains all the sensors needed for an ad-equate test. The test computer communicates with the micro-controller in the motor via CAN the measured values (supply voltage, motor current, rotor position, speed, and temperature).

The test computer itself is integrated into the computer system of the production facility. The production planning and control system (PPC) generates updated files containing the current released production orders (job account number, tracking number, internal part number, product name, and production volume).

The tester adds his or her name to the protocol and scans the bar code of the production document. After that, the test computer identifies the drive in the production order file. For every product, three specific ASCII files are prepared and stored in the test system:

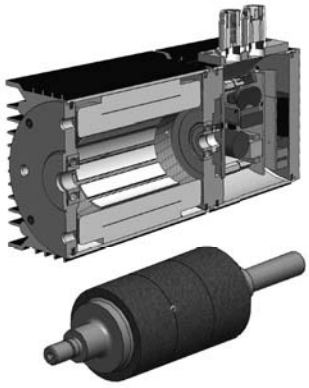


Figure 6: EC motor (MCN 963) with integrated CAN interface for 230-V_{AC} (50 Hz) supply

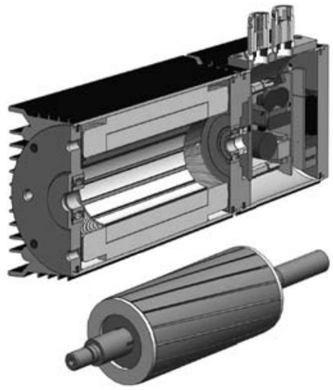


Figure 7: Variable speed induction drive (ACN 984) with integrated CANopen interface

- Test procedure and expected test results
- Rating plate data
- Parameter data at delivery

In the first step of test, the CANopen communication channel is opened and tested. After that, the firmware version of the drive is checked to prevent any errors. (Once a customer tested and approved the engineering samples received, the firmware in this product will not be changed without permission of the customer. Therefore, every product can have a specific firmware version).

In the next step, the information provided by the sensors integrated in the motor is checked. Incorrect Hall-signals, unrealistic temperature values, incorrect voltage values, and DC current values outside the tolerance range can be detected. If the sensors work properly, the digital inputs and outputs and the analog input processed by the 12-bit analog/digital converter of the micro-controller are proofed individually.

Before starting the motor, the power stage of the control unit is tested. In this mode, the control unit works similar to a motor controller for stepper motors. After five steps, all the power switches (MOSFETs or IGBTs) will have been checked.

For the test run, the motor is operated in open-loop speed control mode with 100 % PWM factor. Clockwise and anti-clockwise, speed and motor current are monitored and analyzed. From maximum speed, the motor will be slowed down to standstill. In doing so, the ballast circuit can be examined. As a last test step, the motor is accelerated to maximum speed and the power stage is disabled. The motor will coast. Analyzing the deceleration of the rotor, friction in the bearing system and in the gear can be tested.

After a successful test, the measurement data is archived and the motor is parameterized according to the agreement with the customer about settings on delivery. The parameter set also contains an individual test number for perfect traceability. Then the rating plate with product name, part number, test number and nominal data is printed as an adhesive label and the motor is ready for delivery. ◀

Table 1: Sensors integrated into the motor

Sensor	Purpose
Hall-sensors	- Rotor position detection - Electronic commutation - Speed measurement
Voltage sensor	- Over voltage protection - Under voltage protection - Brake circuit control
Current sensor	- Over current protection
Temperature sensors	- Over temperature protection (motor / power electronics)