Power Electronics Finally Meet with Motion Control

The dynamic development of power and control electronics on the one hand and the demand for more versatile and efficient electric motor control on the other cause us to rethink how we configure and implement drive systems. Thus a highly flexible embedded controller has been developed to complement motor-bridge power modules, in order to better serve the demands of specialized electric motor drive and Motion Control systems. **Ted Hopper, MACCON, Munich, Germany**

There are many inverters on the market for standard variable-speed and automation applications but there is an increasing demand for tailor-made solutions, which can be economically adapted to match specific application requirements and to be cost-effective in low and medium volume.

Power electronic modules and motor control

IGBT Power stage stacks are now available from power electronics manufacturers, which integrate much auxiliary functionality; this includes integrated driver circuitry, current sensing and short-circuit protection. One such example is shown in Figure 1; this is a member of a large family of power stacks, configured as 3-phase H-bridges to supply motor phase currents from 100 A up to 400 A at supply voltages of 600 and 1200 V DC.

Further significant developments have taken place in industry, which have reached maturity during the last few years such as the acceptance of the soft-PLC; powerful, high-speed, bus-communication standards have become established, e.g. EtherCAT, Profibus, RT-Ethernet; the control algorithms of an inverter can now be fully executed in the digital domain, without performance restrictions: and high-speed FPGAs have become available, which can accommodate both hardware logic and microcontroller software. These developments support a new approach to inverter design, the "Embedded Motion" approach.

The term "Embedded Control" is now fully established in industry. A less common but equally important term in the field of electric motor drives is "Embedded Motion". Here the motor and its control/power electronics become an integral part of the target mechatronic system. Further the motor is supplied in kit-form to allow for direct mechanical integration.

Figure 1: Integrated IGBT Power stage stack (Infineon TechnologiesAG)

Embedded motion principle

Employing this "Embedded Motion" philosophy brings a number of advantages. As the motor is directly coupled to the load, two mechanical bearings, a shaft-coupling and considerable additional mechanics are no longer needed – thus the configuration is compacter and lighter. Also the motor-shaft is shorter (and no longer consists of two parts), it is therefore stiffer and has a lower inertia. This allows the servo-response of the system to be more dynamic and frequencies to increase. The servo-response is both quicker and more precise, less energy is required to run the system the motor and target system control can be implemented in the same logic on the same PCB connections thereby remain short (fewer connectors and cables) and EMC is improved better thermal management can be employed, as the integration environment is well known.

There are some applications, which otherwise cannot be successfully implemented, due to their special requirements (with respect to dynamic response, dimensions, mass, environment etc.). Last not least, this configuration will be the most economical in series production, as the choice and scope of parts and materials then used match the application precisely.

What constitutes an inverter?

Let us consider what a modern industrial inverter consists of; it is the sum of the following parts or functions (see Figure 2):

1. power switching devices to provide electric power to the motor (motor-bridge power module)
2. a mains supply including rectification and regeneration protection
3. a communication interface to a host computer or other devices in the control network

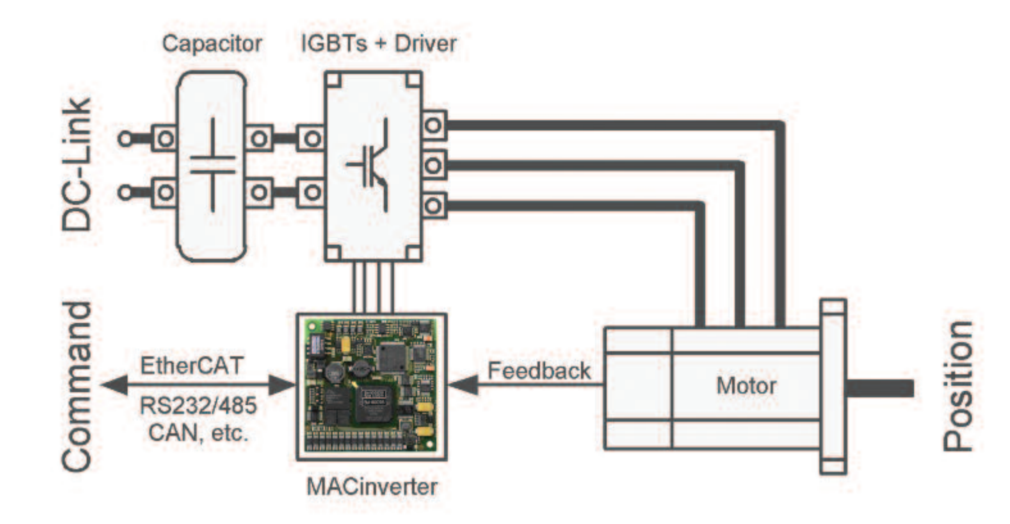

Figure 2: Parts of a motor inverter

4. an integrated PLC or Motion Control sequencer (optional)
5. digital motor control algorithms, fault & safety management
6. auxiliary functions such as housing and interface connectors.

The first two of these functions are largely served by the new power stacks. The next three can now be implemented on a dedicated embedded motion controller board, compatible with standard motor and feedback types, with such features as:

- real-time control implemented in a high-performance FPGA,
- high sampling and PWM frequencies,
- capacity for dedicated customer application functions (in the FPGA or microprocessor),
- extensive library of motor and feedback-control functions,
- powerful host interfaces: Ethernet, EtherCAT, CAN, RS232/422,
- multiple I/O capability (analogue and digital).

The sixth requirement (auxiliary functions - housing and interconnection) can now be implemented exactly to user needs, allowing for both form-factor and environmental specifications.

Embedded motion development platform

A specialized embedded controller (68.5 mm x 68.5 mm x 12 mm, 36 g) has been developed, which is matched to the design requirements of specialized electric motor drive and motion control systems. It incorporates all features needed to implement both simple and demanding electric motor drive systems (see Figure 3). It is compatible with DC, AC and DC-brushless motors and other motor types, e.g. SR and motors with dual or redundant winding systems. Two or more motor power bridges can be controlled from a single card and FET/IGBT power device drivers are switched directly with PWM-switching frequencies up to 50 kHz. Real-time and hardware related control functions are implemented in FPGA logic including torque, speed and position field-oriented control. A comprehensive library of motor-control and feedback signal processing algorithms are available. Feedback devices supported include resolver, incremental encoder (A/B/Z, sine/cosine), Hall–effect sensors, absolute encoders (EnDat, Hiperface, SSI, BISS, Netzer). Host-interfaces include Ethernet, EtherCAT, CAN, RS232/422, also multiple I/Os (analog as well as digital) are included.

Application examples

Combining this embedded controller with a ready power stack allow inverters to be implemented quickly and with minimum development risk, with a free-choice of functionality and to any power rating (currently up to 230 kW).

Examples for possible applications include single-axis, multi-level inverter to special interface and environmental specifications; dual-axis industrial inverter with integrated electronic gearing or back-lash compensation (for antenna control); variable-speed SR-drive; fault tolerant drives with integrated power-stage redundancy for reliability-critical electro-mechanical actuation systems in the field of more-electric aircraft; dual-axis valve actuation control of combustion engines (gas-driven generators); starter-generator control for alternative energy generation systems with mains power regeneration; or twin propulsion drive for an automobile rear-axle, including an electronic differential.

One further advantage of the design approach supported by this embedded controller can be exploited after implementation of the drive prototypes: It is then immediately possible to duplicate the hardware in its final form-factor and interface configuration at minimum expense, still using the same embedded controller board. Only after the application has been fully proven to the final user with the necessary number of prototypes need investment can be made in the industrialization of the final drive product for series manufacture.

Figure 3: Embedded motor controller board MACinverter®