CANopen driver for motion control

By Guido Remmerie (Industrial Products) and Peter Cox (AMI Semiconductor)

By supporting a standardized, generic Power Drive System (PDS), the CiA 402 CANopen device profile for drives allows designers to integrate stepper motors into CAN-based networks, to create low-cost and feature-rich motion-control solutions. In response, approaches to stepper-motor controller design are evolving to enable shorter development times and smaller physical size while at the same time moving greater intelligence locally to the stepper motor.

In addition to enabling control across a network using generic motor-control instructions, emerging controllers will support more sophisticated features such as stall detection and dynamic torque control. The evolutionary path will also provide designers with a choice of architectures to optimize next-generation drives that take maximum advantage of existing investment in controller designs.

Whereas the traditional stepper-motor controller architecture combines a general-purpose micro-controller or digital signal processor (DSP) with analogue driver electronics and a sensor-based feedback loop, these functions are now being integrated into Application Specific Standard Products (ASSP) addressing specific motor-control requirements. These potentially offer a more favorable combination of low cost, fast time to market and straightforward implementation of sophisticated functions. Designers choosing this route typically have a choice of a single-chip or two-chip solution.

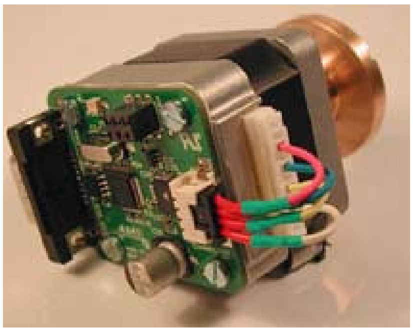

Fig. 1: Stepper controller module

In the traditional architecture, the core controller, with program code typically in Flash memory, delivers a pulse width module (PWM) signal to drive the motor coils. Analogue circuitry amplifies this signal and drives the power stage, which in its turn drives the coils of the motor.

The micro-controller needs to obtain a range of information from the outside world in order to calculate the correct PWM outputs. In particular, it needs feedback on the rotor position. This function is usually fulfilled by a Hall sensor, which not only provides positional information, but can also sense a stall or blocked rotor. Simpler solutions may use an end-of-loop position switch in place of a Hall sensor, while other options include optical position coding or a resistive potentiometer mounted on the motor shaft. In addition to positional data, the controller needs information on the motor current. This typically requires an external resistor in series with the motor driver, which presents the sensed data via an analog digital converter (ADC) as a digital input to the controller itself.

ASSP solutions integrate the controller, speed, position current, diagnostics and power stage functions into one or two devices. They also support sensor-less control strategies. The combination of high-integration and sensor-less control reduces the development time and the physical size. Each approach holds certain advantages for the designer, depending on factors such as performance, cost, and relevant knowledge and IP available in-house.

A two-chip solution, for example, offers advantages where a high drive current is required, or where designers are aiming to maximize the value of existing motor-control expertise and associated software developed for a preferred micro-controller or DSP.

To support this approach, an intelligent integrated motor driver chip takes responsibility for delivering the required PWM waveform at the coils of the motor using only a next micro-step command from the micro-controller. In addition to reducing the bill of materials, compared to a traditional controller architecture, this approach also minimizes the processor loading to the extent that a single micro-controller can potentially control more than one motor.

The use of an integrated driver allows the host controller functions to be as simple or as complex as required. Premium functions may include micro-stepping, which reduces audible noise and step-loss due to resonance, while improving torque at low-speeds. By implementing value-added functions such as a current translation table and special PWM algorithms for reliable current control, the intelligent controller can further offload processing duties from the micro-controller.

An SPI link provides a convenient interface between the micro-controller and intelligent stepper-driver IC, carrying information on parameters including current amplitude, step-mode, PWM frequency or EMC slope control, and monitoring and controlling other features such as sleep modes. This simple, standardized interface can also be used to submit speed, position and coil-current information to the micro-controller, as well as diagnostics such as open and short detection or overheating.

A single-chip ASSP solution combines the capabilities of this intelligent driver with the added capability to translate a target position into the sequence of (micro) steps required to reach that position with the specified acceleration, speed and deceleration. This could be implemented, for example, in a programmable state machine using target-position and ▶

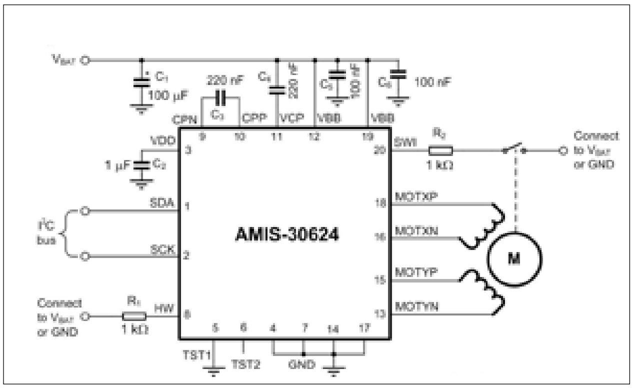

Fig. 2: Single chip controller for stepper motors

other high-level information provided by a remote host and communicated via a bus-level interface such as I²C or LIN. This architecture supports high modularity in hardware and software design, which combines with the inherent scalability of bus-based communication to allow easy extension to accommodate additional axes of movement.

As well as simplifying hardware design, the use of integrated controllers makes it significantly easier to develop and implement an appropriate motion-control algorithm. In practice, this often requires running a characterization algorithm that returns the required parameter setting.

AMIS has used both of these architectures to create stepper controller modules suitable for direct mounting to motor housings meeting popular NEMA standards. This allows direct thermal contact between the module and the motor, which eliminates the requirement for additional heat-sinking and thereby allows operation at high ambient temperatures. By combining the two-chip stepper-controller approach with the AMIS-42675 CAN transceiver and a low-cost micro-controller, the MOD-30522 CAN stepper motor driver module is capable of programmable drive currents up to 1.6 A. A similar family of components, the MOD-3062x, use the single-chip controller architecture for smaller size, and are capable of driving up to 800 mA continuous current in I²C and LIN-connected applications.

Emerging stepper-controller ASSPs are also able to support more sophisticated control strategies, and allow designs to be more closely tailored to application requirements. Two of the key techniques for achieving such improvements are sensor-less stall detection and dynamic torque conditioning.

Stepper motors are mostly used in open loop systems. These have the advantage of being straightforward and also stable, by definition. On the other hand, the lack of absolute positional feedback may allow the driver/positioner to continue driving the coils if the motor becomes blocked. This results in audible noise but - more importantly - breaks the link between the real position and the information stored in the positioner. Some stepper-controller ASSPs are able to detect when such stalls occur by sensing the Back EMF (BEMF) created as the motor coils move within the magnetic field of the motor. This capability can be implemented in either a single-chip or a two-chip solution, and saves the design effort involved in implementing stall detection within a traditional stepper-control architecture.

BEMF detection relies on the fact that the current-carrying motor winding will create an opposing EMF due to its motion within the magnetic field. The amplitude of this EMF is a linear ▶

function of the speed of the motor, and is therefore zero when the motor is blocked.

Like most features and functions, the exact implementation depends on the selected driver architecture. An intelligent driver used within a two-chip solution will likely make the BEMF voltage available on an external pin, allowing feedback to a micro-controller. A more highly integrated device aimed at a single-chip implementation will have this detection circuitry embedded, and will support selection of threshold levels via a convenient link such as I^2C.

BEMF information collected in this way by an ASSP can also be used to implement dynamic torque conditioning. Benefits will include potential reductions in motor size and cost, as well as improvements in energy efficiency.

BEMF is a time-varying function of the velocity of motion of the motor. The phase difference between the BEMF voltage and the current in the coils varies with the mechanical load on the motor axis: as mechanical load increases, the phase difference also increases. The sampled BEMF level will therefore decrease with increasing mechanical load if the BEMF is always sampled at the same time. This phenomenon is known as load angle. If load angle information is provided at an external pin of an ASSP, the voltage drop resulting from an increase in mechanical loading can be detected and compensated by selecting a higher current. This increases the torque of the motor. Such a dynamic torque conditioning strategy saves designers from having to ensure that the motor specification is adequate to handle the peak expected load, and allows a smaller, less expensive motor to be used.

guido_remmerie@amis.com

Safe ride to the South

By Martin Witzsch (Wago Kontaktechnik)

A mammoth project, such as the complete renovation of the traffic control system for one of Europe's major autoroutes, presents the project managers with tremendous problems and also conceals many subtleties - such as 48V technology - in the detail. Niklaus SA has overcome barriers large and small with the Wago-IO-System.It is one of the most important north-south traffic axes in Europe and therefore one of the most frequently used trunk roads in Switzerland - the A2 national route from Basle to Chiasso, often referred to as the Gotthard route. A sophisticated control system saves this traffic artery from collapse. An extensive signaling system prevents queues forming in the tunnel in spite of a traffic volume of six million vehicles per year (as of 2004). A network of lighting systems, fresh air and exhaust air fans, signaling systems, monitoring cameras, radio transmitters, emergency fire alarm and extinguishing systems ensure the greatest possible safety. For this equipment, the Gotthard tunnel alone, which at seventeen kilometers is the longest tunnel on this route, has an installed capacity of 29,000 kW. Fifty kV connections to two power stations in Göschenen (Uri) and Lucendro (Tessin) together with emergency power supplies for the most important safety equipment ensure that a reliable supply is available for the gigantic structure. But the Gotthard is only a small part of the 108 km long route between Airolo and Chiasso for which the Canton of Tessin is responsible. Only by continuously upgrading the equipment, can those responsible cope with the growing streams of traffic. The complete renovation of the traffic control system and all the installations associated with it has been the most recent undertaking. The companies Bergauer AG and Niklaus SA were contracted to carry out this work.

Fig. 1: Jean-Michel Niklaus in the Camorino traffic control center; no alarm goes unnoticed thanks to indicator lamps

I/O system as data highway feeder

The overall route is divided into twenty sections, which have their own control computers. The section length depends on the data point density. Particularly sensitive installations, such as tunnels, form their own section. Two traffic control centers in Airolo and Camorino, which are manned around the clock, monitor the traffic and the equipment. In parallel with the road, a "data highway" in the form of a glass fiber network connects the control computers throughout the Canton. Two sub-networks, Ethernet for connecting the control system computers and a CANopen network for monitoring illuminated signs, supplement the main route.

Of course, the system is not altogether consistent, and, like the A2, has expanded and been modified to suit increasing requirements. The oldest installations have been in service for thirty years. This is where the planners stumbled across the first problems, as many parts of the system are operated with the now uncommon control voltage of 48 V. However, most I/O systems only offer 24-V inputs and outputs. Not so the Wago-I/O-System 750, which was given the go-ahead among other things on account of its high flexibility. Jean-Michel Niklaus of Niklaus SA bears this out: "No other I/O system gave us as many options as that from WAGO". And, in practice, the modular nodes always provide the number and type of connections that are actually needed.

More than 15 000 data points are monitored ▶