Brushing up on motor control

By John Wemekamp

Embedded technologies in ground-based fighting vehicles are often considered to be sensors and weapons plus command, control, and communications subsystems that directly assist the commander and crew to accomplish their mission. However, in addition to these high-profile, compute-intensive technologies, a modern fighting vehicle is a remarkably complex machine with large numbers of motor-driven components such as a turret, gun, hatches, fans, pumps, ammunition handling, and many others. The recent advances in high-power electric motion control and the introduction of hybrid electric drive to fighting vehicles arguably deserves a high placing in the top 10 list of technologies for the war fighter for speed of reaction, reduction of workload, reliability, and remarkable power density.

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The majority of today's fighting vehicles use hydraulics for actuating their mechanical systems. Typically operating at 3,000 to 5,000 psi, hydraulics are prone to leakage and difficult to repair and maintain. In addition, hydraulic pumps, piping, and actuators are bulky and heavy compared to the latest generation of motor-driven subsystems that is set to replace them in the future. Whether the function to be performed is a simple, single-axis operation such as closing a hatch or the much more complex sequence of moves of an autoloader, all closed-loop servo systems share common control requirements to vary torque, acceleration, velocity, and position in order to accomplish their specific functions. Such servo systems use a controller/amplifier that modulates high-voltage dc (up to 610 V) to one or a number of motors to create the motion required. The controller will have a number of inputs such as analog, resolver, or encoder to sense position or velocity to close the loop.

Modern fighting vehicles have an integrated vetronics architecture supporting all the functions necessary to drive and control them. Based on redundant Ethernet or CANbus architectures, bused vetronics systems save on the mass of discrete point-to-point cabling that would otherwise be needed. All functions from external lighting to maneuvering the vehicle or rotating the turret will be transmitted over the vetronics bus as a series of commands to remote controllers located adjacent to the function to be performed. Motor controllers, like other vehicle functions, receive their commands via the vetronics bus. They are most often implemented as Line Replaceable Units (LRUs), complete with considerable intelligence to perform the servo function on command, in addition to handling background diagnostics and local error detection.

Controllers come in a range of types, controlling from one to many axes of movement from one LRU. For a complex piece of equipment such as an autoloader, commands received via the vetronics bus will choreograph a sequence of controlled motions from many motors to select, for example, the required type of ammunition from a dispenser, arm it, move it into position, and load it ready for firing. To accomplish this level of complexity, some controllers are programmable, their specific set of functions being created during development using modeling and simulation tools such as MATLAB and Simulink.

In ground-based fighting vehicles these mechanical components are often large and heavy, requiring a great deal of power to move and position them accurately and safely. Since vehicle weight and size are such critical parameters, demands for power to move heavy components must be traded against weight and physical size of the servo system. The controller is a key element and continuous development is targeted to reduce weight, power, and size of the controller and motors. The success of these efforts can be judged from Table 1, which compares the physical size and power delivery of a typical motor controller with a conduction-cooled VMEbus power supply module.

This level of power density exceeds the capacity of conventional air- or conduction-cooling techniques, requiring both exacting thermal design of the LRU and its components and the employment of liquid cooling. This form of cooling is used in a range of motor controllers produced by Curtiss-Wright Controls Embedded Computing (CWCEC). Designed for a

	Dimensions (inches)	Volume (cubic inches)	Continuous power delivery (watts)	Power density (W/cubic inch)
VMEbus power module	6.2 x 9.3 x 1.6	92.3	750	8.13
Controller/amplifier	5.8 x 8.8 x 8	408	6,000	14.7

Table 1

wide range of high-power, vehicle-based motion control applications, the internal construction and cooling of an example controller are shown in Figure 1.

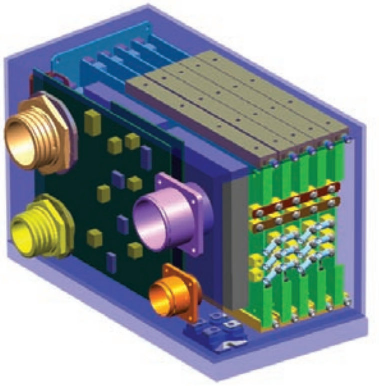

Figure 1

The precise control of the machinery's motion might not be perceived to be as glamorous as a cooperative, networked command and control system or the multiple compute nodes of a synthetic aperture radar processor, but motor control truly stretches its designers and technology to the limits. As a result of this evolution of compact motor controllers, size and weight of modern fighting vehicles will continue to be reduced. This will enable them to be more effective platforms, carrying greater payloads of troops, command and control systems, sensors, weapons, and self-protection systems.

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