Integrated Platform Improves Motor Control Performance in Commercial Aviation

Control for new higher efficiency, lower weight aircraft motors

The vast array of pumps, fans compressors and actuation motors on modern aircraft has transitioned to higher performance variable speed permanent magnet motors. Driving these motors presents some design challenges.

By Michael Toland, Product Marketing Manager, International Rectifier

In order to lower major operating costs such as fuel and maintenance, airlines are driving airframe manufacturers to produce more efficient planes. A key area of focus is the many motors utilized within an aircraft for fuel, environmental and hydraulic control.

Traditionally, the aircraft industry has used fixed speed induction motors with mechanical gearboxes. New system architectures are moving to variable speed permanent magnet (PM) motors because of their smaller size and lighter weight, in addition to their high torque to current ratio, efficiency and power factor. These new motors are designed to drive fuel and liquid cooling pumps, environmental control fans, compressors, and actuation of flight surfaces more efficiently. These new motors, like any new technology, come with design challenges.

First, the development of the motor control so ftware algorithm using a DSP or FPGA requires significant investment in resources and rigorous certification process. Secondly, the motors require electro-mechanical use of Hall sensors for rotor position, which can lead to cable complexity and added reliability concerns.

A high reliability control platform for sensorless vector control of variable speed PM motors (Figure 1) has been introduced to facilitate the transition from geared motors. Utilizing an innovative Motion Control Engine (MCE) with an embedded pre-configured sinusoidal field oriented control (FOC) algorithm IC; benchmark gate drivers; MOSFETs and feedback electronics, the new approach provides complete drive control in a robust, small footprint and lightweight plastic package.

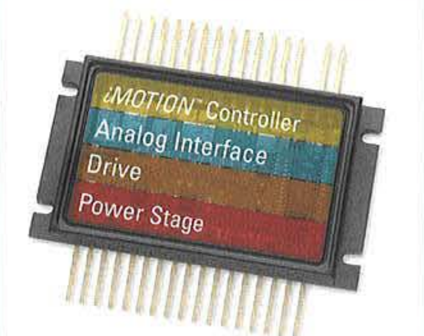

Figure 1: IRMCT3UF1integrated motor module.

The new integrated motor module, which is MIL-STD-883 certified is supported by design tools that enable the user to quickly configure the motor drive in a variety of configurations to a specific application. Since the control algorithm is a hardware-based IC dedicated to motor control, certification requirements are simpler than those designed for a software-based algorithm programmed into a microcontroller or FPGA, resulting in a rapid, cost effective time-to-market solution for electric aircraft system integrators.

An Integrated Approach

In existing solutions, digital motor control is typically designed using a DSP, microcontroller or FPGA-based software program, requiring a team of software design engineers to write and debug the code.

However, a new approach using an integrated motor control module, International Rectifier's iMOTION™ IRMCT3UF1, incorporates a unique hardware-based Motion Control Engine™ (MCE) IC (Figure 2) to perform the same function previously delivered using a resource-and time-consuming DSP or FPGA alternative.

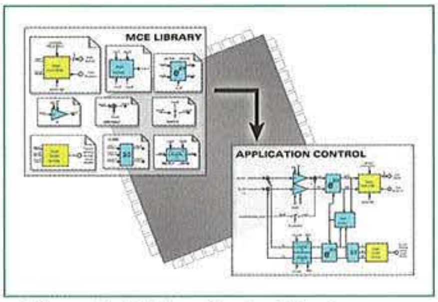

Figure 2: Motion Control Engine.

A companion development tool, ServoDesigner™, expedites software development by providing a simple menu-based selection process where motor design and user defined parameters such as ramp time or maximum speed are organized a drive parameter spreadsheet. Upon completion of the motor design, the final design parameters and the user defined parameters are entered into the development spreadsheet. ServoDesigner™ translates the motor parameters and stores them within the module, enabling the motor designer to quickly evaluate the performance of the motor. Diagnostic tools are also available to aid this process.

This hardware-based control scheme dramatically reduces the number of man hours required from months to days to obtain mandatory certification and can be easily duplicated for each motor drive.

Sensorless Digital Brushless DC Motor Control

The Motion Control Engine (MCE) IC allows the designer to control motors up to 500 VA without software development or the use of Hall sensors to determine the rotor position. Without Hall sensors for position sensing, the rotor must start in a known location. In order to gain control of the motor the rotor windings must be spun and parked to the known position. The goal is to maintain an orthogonal relationship of the stator and rotor windings. The stator winding back EMF is a function of the motor speed, and the stator currents are a function of the back EMF and applied voltage. The rotor position can be calculated and the signal fed to the space vector PWM modulator and the appropriate gate signals applied to switch the MOSFET. In addition, inverter leg shunt current sensors are used to feed back phase current to the digital controller in order to provide the maximum torque and maintain speed. The rotor angle with respect to the stator is estimated every 11 microseconds to provide a smooth operating drive with minimal torque ripple.

The sensorless algorithm operates over a continuous speed range of 10 percent to 100 percent of full speed without overload for greater performance. Removal of the Hall sensors reduces the motor cost while significantly improving reliability.

The module is designed to shut down during an over-current, over-temperature, or an over- and under-voltage event. Phase currents are monitored. If the safe condition is exceeded a gate kill signal is applied and a fault occurrence is indicated. At this point, a restart sequence can be initiated which includes clearing the fault.

A thermistor is mounted on the IMS substrate board in close proximity to the power silicon. If the substrate temperature exceeds the safe limit of 105 degrees C a gate-kill signal is asserted. The DC bus is also monitored for under-voltage and over-voltage conditions and minimum and maximum speed conditions. Operation outside these preset limits will also produce a fault to protect the load. To clear the fault condition a fault clear pin is provided to initiate restart sequence. Communication to the device is done via an RS-232 serial interface and can be used for longer cable lengths or noisy environments. Additionally the module uses an error detecting protocol to maintain the integrity of the host registers.

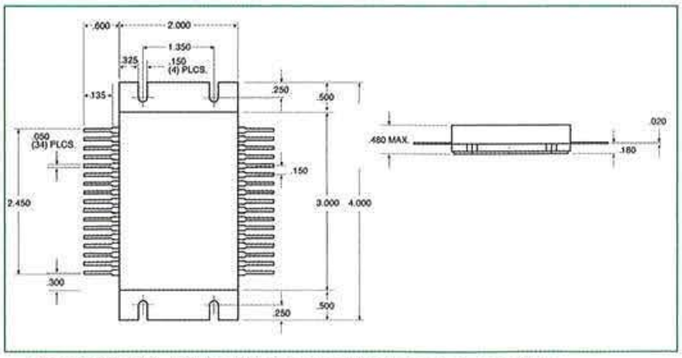

Figure 3: MIL-PRF-38534 qualified power module.

Gate Drive Circuitry

Based on selected parameters, the proprietary algorithm within the digital controller ultimately controls the gate driver integrated in the motor control module and the switching of the power semiconductors during commutation.

The optimized chipset including the control, gate drive and power MOSFETs and intellectual property have been combined with rugged packaging to meet vibration profiles in a small lightweight footprint ready to mount on a cold plate or heatsink.

This integrated package (fig 3) approach also incorporates a fully qualified power MOSFET mounted on an insulated metal substrate (IMS) close to the gate drivers for the lowest possible inductance. Each lot is screened to military specification MIL-PRF-38534 to ensure the highest level of reliability and rated at the full operating temperature range of minus 40 to plus 85 degrees Celsius.

Conclusion

The trend in aircraft design is towards more efficient brushless DC motors. A new approach using an integrated motor drive module for brushless DC motors dramatically reduces the effort of programming the motor control and simplifies the certification process. Because the device is configured for sensorless field oriented control the elimination of Hall sensors improves reliability while reducing component count to simplify design and increase performance in variable speed motors used in electronic aircraft to achieve greater fuel economy and lower maintenance costs.

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