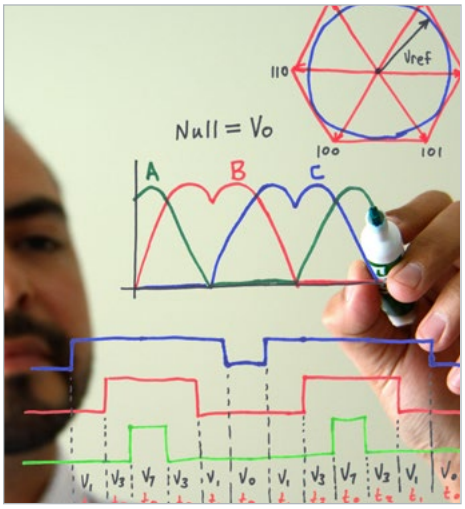
Innovative Drone Propulsion Design using Model-Based Development



Field-oriented Motor Control PWM Wave Forms. Making Space Vector Modulation Look Easy.

Key Highlights

Industry
Electronics

Challenge
Develop Robust Motor Control for Drone Applications

Altair Solution
Using Embed for high speed simulation of motor electronics and control dynamics to develop a novel method of sensorless field-oriented control.

Benefits
- speed of simulations
- flexibility in parametric data entry
- fast 2D and 3D plotting
- increased product quality

Kappa Electronics (www.kappaiq.com), a consulting firm specializing in motor control systems with 70+ years cumulative experience and a deep background in the industry, prides themselves in solving complex problems while providing excellent customer service. They start each project with the goal of doing things in a better, smarter way than anyone has done before.

When a customer came to them requesting assistance with controlling the motor for a new drone design, they chose Altair's solidThinking Embed® software to assist them. Embed (formerly known as VisSim Embedded), a visual environment for model based development of embedded systems, fit the criteria they set forth. Its fast simulation speed, quick diagram editing, deep data input, 2D, and 3D plotting capability shortened the development time and increased product quality. With solidThinking Embed, they could quickly develop virtual prototypes of any dynamic system, vary parameters of the system, and verify that the system performed as required.

Developing an Observer to Observe the Observer

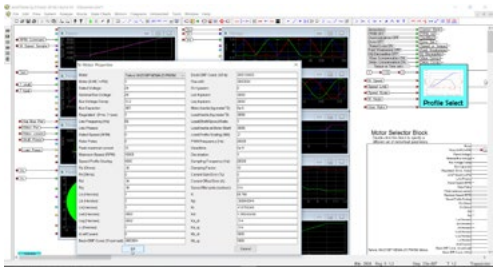
In order for field-oriented control to work properly, it needs to know the angle of the rotor flux with regards to the stator frame. It is possible to use an angle sensor on the motor's shaft to get this information, but shaft sensors are usually very expensive, and totally impractical for a drone application, where cost and weight are critical. Kappa's strategy was to develop an observer that would estimate flux angle by measuring the motor's voltages and currents. Kappa came up with a multi-mode observer structure that would dynamically reconfigure itself based on operating conditions to provide the best estimate of flux angle over a wide range of operational requirements.

Keywords: Embed, Kappa Electronics, sensorless field-oriented control, drone application, model based development, embedded systems

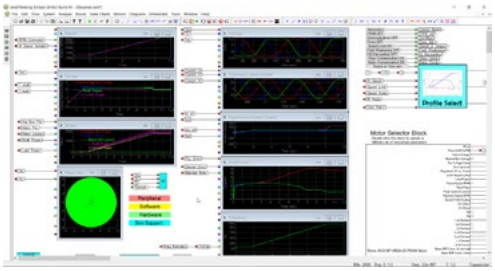
Kappa Electronics Success Story

"If not for Embed, I'm not sure how we could have simulated this job for our customer. As a tool, it has all the features we need to simulate any motor control application, quickly and accurately."

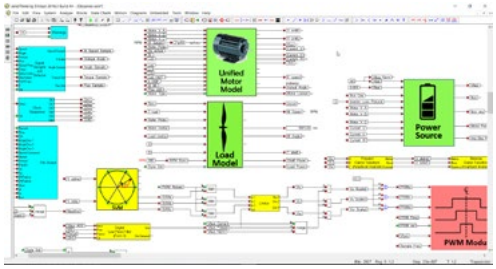
DAVID WILSON
Owner
Kappa Electronics



Use of parametric data entry. All parametric data can be loaded with one click of the mouse.



Motor response to ramp speed command with power, torque and PWM command and phase to phase voltage. Virtually unlimited graphing capability.



High level view of system simulation with FOC control, motor and load.

With the observer designed, they began testing its performance. They had to deal with motor frequencies ranging from 40 hertz to 2000 hertz; a challenge in and of itself. In addition, the observer performance needed to be qualified over a wide range of torques and parameter variations. If the observer failed to perform under any of these conditions the drone would drop from the sky, which is [obviously] unacceptable.

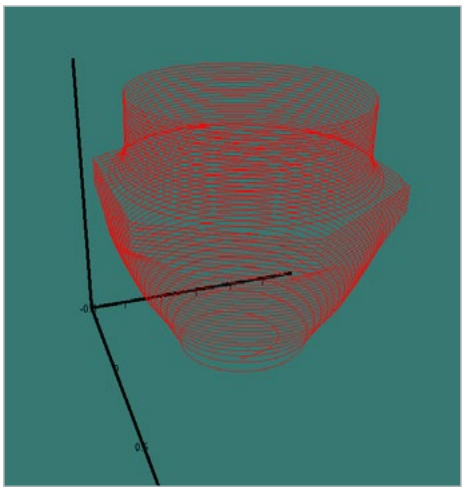
Knowing what they needed to confirm, Kappa developed a battery of tests designed to assess the cogency of the observer. The simulation included a field-oriented control model complete with a motor model, a propeller load model, and a model of the observer itself. They varied motor parameters in the virtual motor, but kept these changes hidden from the observer to test how sensitive it was to parameter estimation errors. This was done by tracking the difference between the observer's predicted flux angle compared to the actual angle of the virtual motor model. In the process, they used Embed's file output capabilities to generate over 600 plots of characterization data. The graphs indicated an amazingly low angle error and suggested that the observer should not lose angle-lock, even under very adverse conditions.

The Features Made the Difference

The basic configuration of solidThinking Embed® includes the tools needed for simulation and embedded development, including state charts, target support, fixed point algorithms, efficient code generators, motor control libraries, and a lot more. This results in an easily configurable development environment. Kappa exploited Embed's robustness, bug-free operation, and complete backward compatibility to move their project forward very quickly.

Flexible "Dialog Table" Block Reads Excel Spreadsheets

Kappa was able to input a spreadsheet into Embed containing all the simulation scenarios they would need. Items such as bus voltages, tuning parameters, motor parameters, sample frequency, PWM frequency, etc. were imported as a single row in a spreadsheet. This allowed them to easily go from one simulation scenario to the next by simply changing the row selector in the Dialog Table box. With a click of a button, Kappa was able to see how the design would work under dramatically changing conditions.



V alpha, V beta, Time Plot of the FOC Controller Response in Time as Torque Demand Increases.

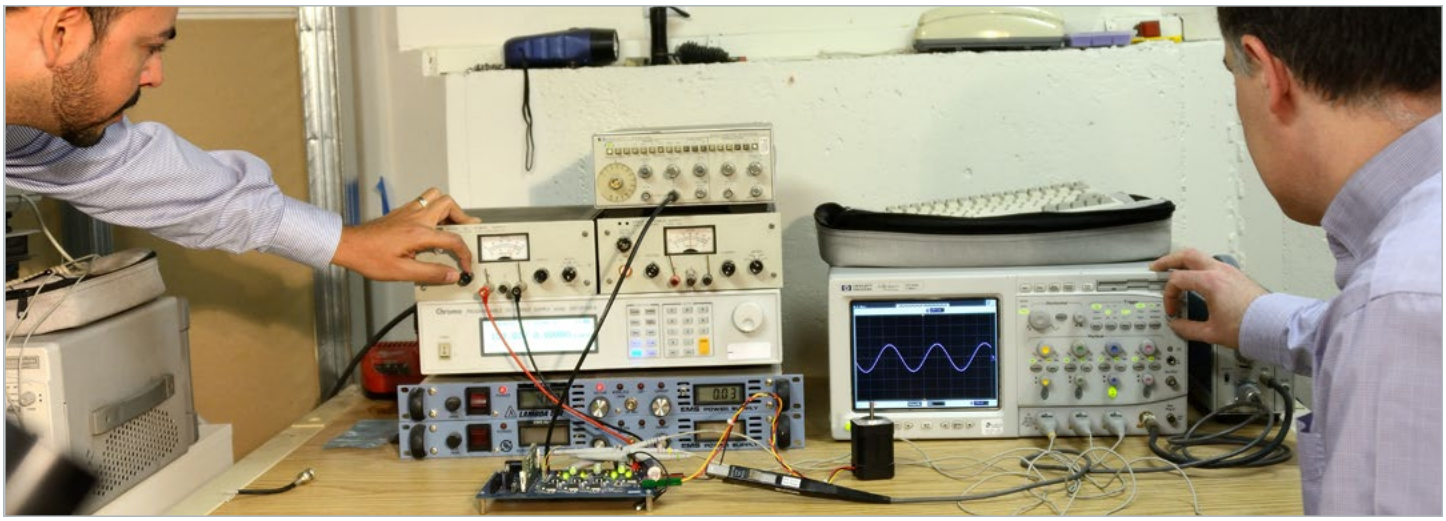
Motor Control seminars.

3D Visualization

The 3D feature in Embed allowed Kappa to represent the three-phase voltages applied to the drone motor as two voltages (V alpha and V beta), which were plotted on an XY 2D plot. Taking this one step further, they were able to plot it with time as the third dimension, giving them a three-dimensional spiral of the space vector voltage output. With one glance, they were able to determine exactly how the system performed over the entire simulation, identify exactly when it would go in and out of overmodulation mode and whether any anomalies existed in the control loop. “This is one of my favorite features of Embed”, said Dave Wilson, Owner of Kappa Electronics.” “It draws hi-res 3D plots so quickly, and is very fluid! It is much more informative than a standard two-dimensional space-vector plot.”

Solving Complex Problems – Adhering to Core Principals

With Embed’s multi-core task-threading capability, Kappa was able to take advantage of Embed’s execution speed to iterate quickly to test and modify design assumptions. When the finished observer model was finally translated into actual code and tested on a real drone system, it behaved exactly as the simulation predicted. Angle errors were exactly in the range predicted by Embed. “If not for Embed, I’m not sure how we could have simulated this job for our customer”, Dave said. “As a tool, it has all the features we need to simulate any motor control application, quickly and accurately.”



Debugging complex motor control systems.

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