MOTOR CONTROL
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# Reference Information on Modulator Stability

On page 2 of Volume 1, Issue 4 (Introduction to BLDC Motor Torque Control - Part 2) subharmonic oscillations are discussed as representing a form of instability. It is then mentioned that for duty cycles above 50% slope compensation can be employed to extend the useful operating range of the modulator. For the interested reader, we recommend some papers written by Ray B. Ridley. These papers show how a simple high frequency extension to the current loop transfer function model can predict subharmonic oscillations. They also predict the precise amount of slope compensation required to dampen the unmodeled dynamics and stabilize the inner current loop over a wider operating range.

While the Ridley papers specifically address power supply applications (where the output voltage is typically constant) the analytical techniques are useful and can be extended to the inner torque control model used with BLDC motors. That is, the high-frequency model extension provides an analytical tool that supports general empirical results. These papers provide some insight to the origin of the oscillations, how to predict them ahead of time, and show the usual compensation circuit used to counteract the problem.

A typical power supply cookbook explanation of slope compensation is also found in:
Switching Power Supply Design, Abraham I. Pressman - 2nd Edition, 1998,
McGraw-Hill, Chapter 5: Current Mode Control, Sections, 5.5.1-5.5.5.

An abstract (and Acrobat paper) of the essential Ray B. Ridley work is found at:
http://www.ridleyengineering.com/papers.html
Ridley, R. B., **A New Continuous-Time Model for Current-Mode Control**
http://www.ridleyengineering.com/downloads/curr.pdf
IEEE Transactions on Power Electronics, April 1991, pp. 271-280.
(Special issue on Modeling for Power Electronic Circuits and Systems.)

The accuracy of sampled-data modeling is combined with the simplicity of pole-zero representation to give a new current-mode control model, accurate to half the switching frequency. All of the small signal characteristics of current-mode control are predicted, including high-frequency subharmonic oscillation which can occur even at duty cycles of less than 0.5. The best representation for the control-to-output transfer function is shown to be third-order. Model predictions are confirmed with measurements on a buck converter.

*The first model simultaneously allows prediction of the current-loop instability, transition from voltage-mode to current-mode control, and a simple pole-zero representation. The paper shows why you have to use a three-pole representation of a current-mode system to get results which closely model those seen in the lab. A fully expanded version of this paper is to be found in Dr. Ridley's dissertation, for those interested in the complete details and history of current-mode modeling. Send e-mail to:* info@ridleyengineering.com *to get information on ordering this dissertation.*