Delta-Sigma Modulation Technology in Electric Drives

Delta-sigma modulation is widely used in measurement systems and audio. With the widespread use of isolated delta-sigma modulators this technique was implemented for shunt current sensing in electric drives and power electronics.

The tutorial will start with the general information about delta-sigma modulation, its demodulation by means of digital filters, shunt current sensing, and its accuracy analysis. Then, the same approach will be used to increase the accuracy of the speed measurement using incremental position encoder as its signals being captured by microcontroller produce delta-sigma modulated data. Then, a similar approach will be applied for a model predictive control system where the hysteresis element is considered as a source of delta-sigma modulated bitstream.

The tutorial is based on the experience of developing the control systems for high-performance electric drives and power electronics converters. All the considered methods will be supported by experimental results and practical application examples.

This tutorial is designed to be valuable for students, academic staff, and practicing engineers who want to deepen their understanding and practical skills in modern sensing and control strategies.

The tutorial is planned for 2.5 hours, followed by a Q&A session.

Content

Introduction

What is delta-sigma modulation?

Current measurement using shunt current sensors with delta-sigma modulators

Schematics of current sensing circuit
Filtering delta-sigma modulated bitstream
Estimation of measuring accuracy
Operation of the closed-loop systems with shunt current sensing
Short-circuit fault protection using shunt current sensing with delta-sigma modulators
Examples of industrial solutions with shunt current sensing
Are there any other delta-sigma modulated signals in electric drives?

Precise speed measurement using incremental encoder as a source of delta-sigma modulated data

General information about incremental position encoder
Review of the speed measurement methods and accuracy analysis
Processing signals of incremental encoder as the delta-sigma modulated ones for measurement at high speeds
Computation complexity of the methods for implementation using modern microcontrollers

Model predictive control with reduced integration step size

Overview of model predictive control strategies
Introduction to MPC with reduced integration step size and processing hysteresis control as delta-sigma modulated voltage reference
Simulation and experimental results

Conclusions

Biography

Alecksey Anuchin (Senior Member, IEEE) received the B.Sc., M.Sc., Ph.D., and Dr.Eng.Sc. degrees from Moscow Power Engineering Institute, Moscow, Russia, in 1999, 2001, 2004, and 2018, respectively.
He is the Chair of Joint Chapter IE13/PE31/PEL35/IA34, Moscow, from 2021. He is in a head position at the Department of Electric Drives, Moscow Power Engineering Institute for the last ten years. He has more than 25 years of experience covering control systems of electric drives, hybrid powertrains, and real-time communications. He is the author of three textbooks on the design of real-time software for the microcontroller of the C28 family and Cortex-M4F, and control system of electric drives, in Russian. He has published more than 150 conference papers and journal articles. He delivers lectures on “Control Systems of Electric Drives,” “Real-time Software Design,” “Electric Drives,” and “Science Research Writing” in Moscow Power Engineering Institute.

Prof. Galina Demidova (Senior Member, IEEE) received her Ph.D. from ITMO University in 2018 and currently Head of the “Electric Drive Systems Engineering” education program at ITMO University (Russia). She also holds professorships at Hangzhou Dianzi University and Changchun University of Science and Technology (China). With over 18 years of experience in control systems, neural networks, machine learning, wind turbine technologies, and precision engineering, she has contributed to more than 100 scientific publications and over 70 industrial projects. Prof. Demidova is an expert in precision systems for biomedical and tracking systems applications, with advanced control techniques.