Dynamic Error Budgeting, a Tool for Designing High Precision Devices

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Introduction

Different aspects limit the performance of high performance motion devices. In advanced mechatronic applications the feedback control will make sure that static errors, as measured by the system sensors, will be equal to zero in the undisturbed state. During normal operation however systems will be subjected to many different disturbances. The power of the controller to counteract the effects from such disturbances is generally limited and thus accuracy, as measured at the system sensors, is limited.

During the design of new systems it is required to be able to predict the performance at the earliest possible moment. To be able to give such predictions, models of the system behavior are generally made, for instance using FEM tools. Such models, when properly used, allow to design suitable stabilizing control schemes. In many cases the design will be optimized to achieve a certain dynamic response or a certain error correction capability as a function of frequency. For the client it is however required to predict the position errors as a function of time under the influence of all potential disturbance sources.

The "Dynamic Error Budgeting" approach builds upon the use of Parseval's theorem linking frequency domain and time domain data. In this method the different disturbance sources are identified during design. Suitable estimates of the magnitude and frequency content are determined and used to act upon the model of the controlled system. The frequency transfer functions of each disturbance to the performance parameter of the design are used to calculate the Power Spectral Density of the performance. Based upon this information the total performance in time domain, statistically expressed, can be calculated. The individual contributions can be identified and the dominant dynamic effects can easily be seen in the "Cumulated PSD" over the relevant frequency domain.

The practical application of this method will be presented in the design of a precision rotary drive for future optical disc mastering equipment. This drive, based upon the application of electro-magnetic bearing application, must allow for rotation with asynchronous error motions below one nanometer standard deviation. Disturbances from external vibrations, amplifier noise, DA-conversion and sensor performance have been incorporated. During the design trade offs and improvements based upon results from Dynamic Error Budgeting approach have been successfully used.

From the presentation it will become clear how this method can be used in early conceptual phases of system design to select suitable options.

Key Words: dynamic error budgeting, system design, mechatronics, magnetic bearing