# Introduction

Field oriented control (FOC) is a well-established startegy for the control of high performance electrical drives [1]. An essential part of this concept is the inner current control loop [2]. A prerequisite for the proper operation of the outer control loops is a precise and rapid digital current controller [3]. In order to achieve the desirable performance of the overall control system high current loop bandwidth is imperative [4]. Robustness at high output frequencies, along with a decoupled d and q axis transient operation is also required [3-5]. Digital control introduces delays due to the sampling process, execution time and digital pulse width modulation (DPWM) [6]. These delays limit achievable bandwidths and can have considerable influence on the system dynamics unless current controllers are properly designed [7]. The concept of multisampled digital control offers significant reduction of the modulator delays and therefore is a promising solution for breaking the bandwidth limitations [8]. The multisampling approach implies that the control variables are sampled, and thus the duty cycle is adjusted, more than two times per switching period [9].

Synchronous rotating frame (SRF) PI controllers are the most frequently encountered current control concepts since they are simple and successfully cover the majority of the industry requirements [2,7,10]. With a proper parameter setting procedure, high bandwidths can be achieved [2,7]. Nevertheless, their transient decoupling capability is rather limited, especially at high speeds [11]. On the other hand, model predictive dead-beat current controllers offer very fast transient response but at the cost of considerable performance degradation when parameter mismatch occurs [12,13]. Since saturation and temperature variations are very often encountered in electrical drives, a simple dead-beat approach might lead to insufficient performance. An FPGA implementation of the robust multisampled dead-beat control has been proposed in [14]. Another promising current control approach is the discrete internal model principle design [15]. Since no S domain based delay approximations are used, axes cross-coupling is inherently eliminated and high closed loop bandwidths can be achieved [16,17]. Despite all of the benefits of feedback averaging, the addition of a moving average filter in feedback path can considerably degrade the performance of the current control loop [17]. The IMC concept however, with some enhancements of the controller structure in terms of addition of differential compensator and advanced scheduling scheme, achieves very fast and robust current tracking even with MAF in the feedback path [18]. Further improvements in terms of active resistance feedback result in high disturbance rejection capability [19].

This paper proposes a novel multisampling control strategy for electrical drives which is suitable for implementation on standard DSP platforms. The goal is a multisampled IMC current controller which offers robustness, high bandwidth and stability margins and better performance than the state-of-the art double update rate solutions. The first step is to derive an appropriate analytical model of the load. Next, this model is used to determine controller structure and perform parameter settings. In terms of controller structure and feedback acquisition, three cases will be considered: 1) IMC controller from [17] with MAF; 2) IMC + differential compensator with MAF [17]; 3) IMC without MAF. For each of three cases an adequate benchmark case is determined with an aim to show that the proposed methodology surpasses benchmark controllers. The target is to show that with the multisampling approach delays introduced by feedback averaging can be successfully eliminated, enabling both robust and error-free feedback acquisition and a high dynamic performance of the current loop.

This paper is organized as follows. Section II addresses discrete time machine model, controller structure and analyzes delays introduced by feedback averaging, calculation and DPWM. The multisampling PWM approach, with an outline of its merits and demerits, is explained in Section III. A DSP implementation of the multisampling algorithm is also presented. Exact controller structures and parameter setting procedures for the three aforementioned cases of interest are derived in Section IV. Effectiveness of the derived analytical model is illustrated via simulated current loop step responses and frequency response analyses. Comparison between performance of the proposed methodology and benchmark controllers is also provided. Experimental results are shown in section V. Conclusions are drawn in section VI, along with a proposal for further studies on the presented topic.