# Analysis and implementation of Multisampled PWM for high bandwidth and output frequency current control of electrical drives

Important to know for writing. Everywhere where you claim something, it must have a credible reference next to it. Try not to write too cocky sentences, if you are not **absolutely** sure it is facts (it is always better to smoothen sentences, writing things like: most likely, it is under investigation, etc…)

# Paper organization by sections:

## Introduction

Introduction should be organized in three paragraphs. The entire introduction should fit on one double-column page (maybe slightly go over on second one).

The first one briefly explains the necessity for high bandwidths, output frequency operation for current loop. Also, it introduces very short explanation (and call to reference) that digital control introduces delays, which limit the achievable bandwidths with respect to current control. In the end of the paragraph we introduce the paradigm of multisampled control, with important references. It hints that we will use it to break the bandwidth limitations. (5 – 6 references total)

The second paragraph contains comparison with so far achieved results. Here we should mention few cases with model predictive control (such as dead-beat), with its demerits (parameter dependency – specially tricky for machines due to saturation and temperature changes). After that, we say few cases about directly comparable approaches (perhaps here it is Vuksa’s paper only, or add the first paper with discrete IMC design (Lorenz 2010)…). We say what they have achieved, and emphasize limitations of their methods. (5-6 references)

The third paragraph we use as a **clear, concise**, manifest of what we are going to do. We say that we use regular industrial DSP, so no fancy FPGA platforms etc…

## Machine model and control loop

Here we need to introduce the machine model, and control loop block diagram. The result is discretized plant transfer function (like in Vuksa’s paper), that we explain is exact discrete-time model (completely exact only for double and single update, for multisampling, we model it like this, being aware of its limitations). We give the controller structure (perhaps just discrete IMC, or also PI if we want to include these results in the paper – why not), and we analyse the important part – delays introduced by calculation and DPWM zero order hold. After this, we go into feedback branch (filtering). We mention Vuksa’s reasonings to why current loop should always contain feedback averaging for motor drives, and we include the improved controller structure with derivative gain.

## MS-PWM approach

This section explains MS-PWM, its merits and demerits. Here we need to state if and why we are going to use those MAFs (problems with vertical intersections), we must also mention different approaches, such as repetitive filters (more prone to noise than MAFs), etc… Here we can fit the part of the DSP implementation of multisampling (my algorithm). We also say that this is helpful for MS-PWM (with references) as it reduces nonlinearities due to vertical crossings and similar. We provide the analysis to how much phase lag is introduced by filtering. In the end, we make a comparison to how much total phase lag we have for each of the important cases (discrete IMC without filtering, discrete IMC with filtering and one step calculational delay, discrete IMC with filtering and advanced scheduling, discrete IMC with MS-PWM – our case). This needs to indicate that we will be better regarding delay, which will also enable us to achieve higher bandwidths.

## Decoupling at high speeds

Here we must do some analysis regarding decoupling effect (averaging in dq or in alpha-beta) – if we are going to fit this in the paper. The result should be some kind of metrics that tell us that we will be able to do better decoupling at high speeds compared to double-update.

## Simulation results

Here we must show everything that we will later also show in experimentals.

Exact explanation of compared controller structures and gains (s-domain based design, comparison of our controller without derivative gain with UR = 2 without filtering, and of our controller with derivative gain and Vuksa’s best controller.

Comparison between step-responses, perhaps frequency response analysis, indicate all performance margins (stability margins, overshoot, rise time, coupling).

Besides this, we must also do a comparison of very high-speed responses, to demonstrate better decoupling.

We can also give example of much better response without any MAFs with multisampling, but with all demerits induced by MS-PWM (ripple and discontinuities in the feedback). These results must hold the spectral content of the current (THD tends to worsen with MS-PWM without filters).

These results can be also performed in HIL as well as in SIMULINK.

## Experimental results

Simple confirmation of all we showed in simulations (or at least of all we can get).