A Reconfigurable System-on-Chip-Based Fast EDM Process Monitor

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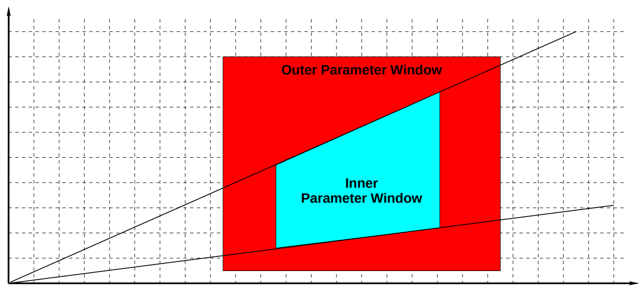
Background

The electric discharge machining (EDM) based material erosion is a result of several thousands of microplasma channel discharge phases between the tool electrode and the workpiece, which are controlled by a complex, high-energy impulse generator. Besides the parameters of the generator (e.g. discharge duration and current), the gap distance between the tool electrode and the workpiece as well as its electric behavior have a significant influence on the process properties. Since the gap distance and its physical consistency cannot be measured directly, process prediction is achieved indirectly through discharge impulse ignition statistics observation. As a part of the machine development effort, every tool electrode/product material pair refers to its own, discrete, manually optimized process parameter set. To perform the EDM process economically, we apply a continuous process model, which allows exploration of the whole parameter space, even at runtime. This can be achived through a highly adaptable impulse classification and monitoring system, which avoids the use of fixed, hard-coded sub-optimal parameters. The monitor has to be configured dependent on the electrical properties of the pulses specific to the material to assure maximum process observation accuracy. Therefore, the hardware may be software-programmed (short-term adoption) or reconfigured (long-term adoption) to a specific process parameter window.

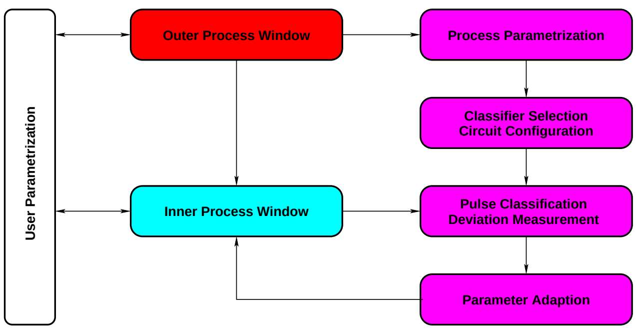
Parameter Window



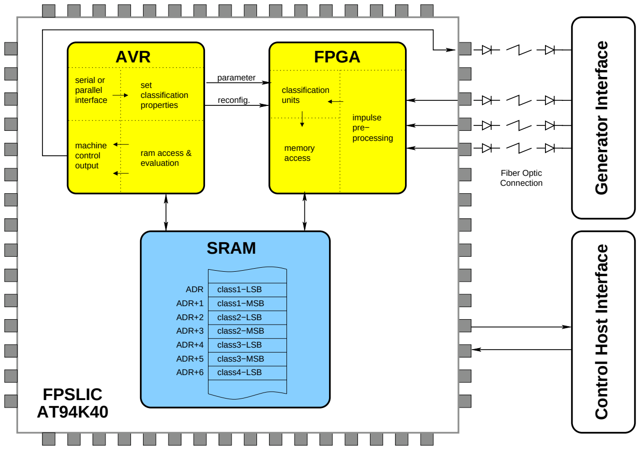
Evaluation Framework

According to the proposed impulse monitor an evaluation framework was created, which made it possible to implement a trend analysis for the process of sinking electric discharge machining over a very large number of impulses (several thousands) during a long period. Several impulse properties a measured and classified, including the ignition delay and the rise/fall times. The histograms obtained thereby supply predicates about process conditions. Based on these results, parameter changes for automatic feedback control can be extracted, which will be transfered to the machine. Another very important feature is the recognition of pulses beyond the process parameter window.

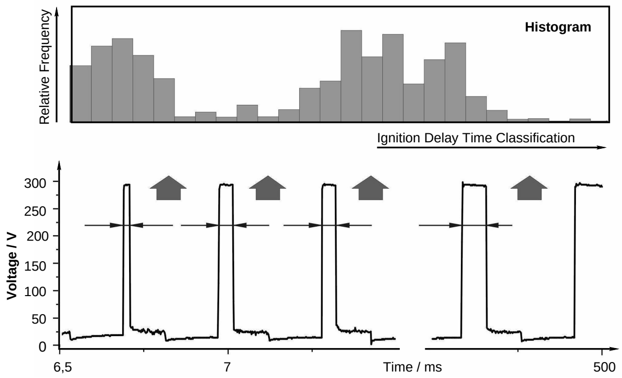
EDM Process Adaption



System Architecture



Impulse Classification



Implementation

We chose Atmel's Field Programmable System Level Integrated Circuit. The classifiers are implemented as a parameterizable VHDL model, which can be tailored to the material spezific properties (outer process window). For a two-dimensional classification, the circuit consumes about 30% of the FPGA logic ressorces. A maximum clock speed of 45 MHz is achievable.

Conclusions

The reconfigurable SoC-based architecture provides a power- and area-efficient solution compared to a classic FPGA microcontroller board, where high speed memory access had to be performed across a parallel bus system and an additional, external SRAM chip would be necessary. This is an important fact, since the EDM control system operates in a highly EMI critical environment. In contrast to other systems, it is possible to put the process window anywhere in the parameter plane through circuit reconfiguration. As we consider the enhancement of the parameter dimension, we see an upper bound for the scalebility of the classification units. Since the on-chip RAM is constructed as one monolithic block, parallel RAM accessability is an inherent problem of the FPSLIC architecture. Our described system can be applied for optimization of the sinking electric discharge machining process in its current state. Circuit timing is a subject for further improvements to enable the exploration of the more critical wire electric discharge machining process.

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