A Novel Zero Crossing Quantifier

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***Abstract*— Detecting zero crossings is crucial for low EMI, high efficiency power electronics. A novel circuit to detect additional magnitude related essential parameters of zero-crossings is presented. Using active noise suppression and zero referencing a novel magnitude detector has been designed. Excellent performance, even under complex crossing is shown for this proof-of-concept realization.**

***Index Terms*—Power Electronics, EMC Reduction, Denoising**

I. Introduction

Zero crossing detectors have been investigated by multiple authors. Its main application can be found in switched power converters for EMC control. Comparator based system using digital counters are explained in an early publications [1-3]. Advanced concepts based on FPGA, directly used for gate control are shown by Yang Wang in [4]. These research works focused on the timing of the zero crossing and no further improvement is to be expected using this approach. Based on these previous designs, our research group has realized that a significant reduction in EMC can be achieved by exactly detecting the magnitude, including polarity during these essential switching events. The design is based on active noise suppression and includes secure data storage.

II. METHODOLOGY

To precisely detect those complex zero crossings, this novel detector, named "zero crossing quantifier" (ZCQ) was developed, Fig. 1. Its core functionality is based on multiple subcircuits needed for realizing the ZQC.

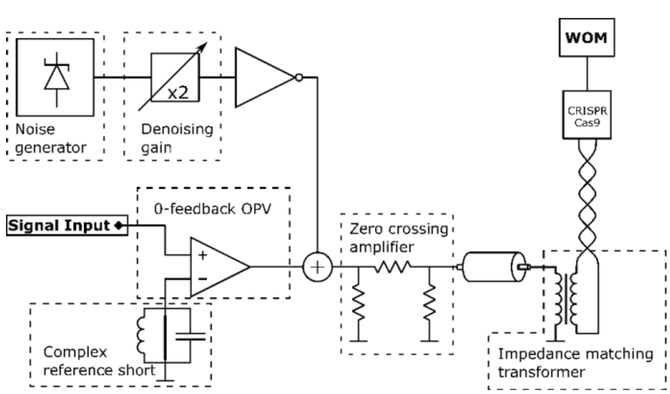

Fig. 1. Zero Crossing Quantifier

The incoming signal is compared to the reference short by a unique 0-feedback Op-Amp. A precision noise source, based on a noise diode to replicate semiconductor created natural system noise, delivers a predefined noise signal which is amplified and subsequently subtracted from the sample signal. The adjustable gain allows to set the de-noising level amplifier. Empirically, it was shown that a factor of 5.7 decreases the signal's noise floor beyond detectability at a level of -191.00 dBm/Hz. We framed this level as double zero "0", as it forms the optimal noise floor reduction otherwise only achievable in cryogenic, superconducting amplifiers.

Two 10 dB attenuator are used to further correct the amplitude of the pre-processed zero crossings. The amplifier is realized in a double PI arrangement to avoid the phase shift of a PI style attenuator. A standard LAN arrangement is used to transfer the zero crossing sequences into a secure a write only memory (WOM) [5]. This type of memory structure was selected to fulfill the requirements set by the European General Data Protection Requirements GDPR.

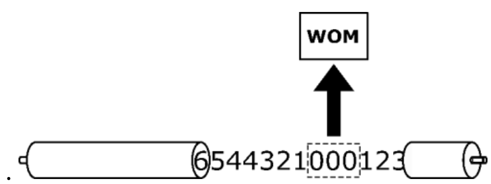

Fig.2. Magnitude extraction out from value stream

III. Discussion

Initial tests have shown a reduction of emissions level in resonant power converters by at least 10 dB using the ZCQ. The main reduction is achieved by reducing switching events in the power electronics circuit as the ZCQ detected magnitude is used to drive the gate.

A drawback of the proposed ZCQ concept is the loss of the information related to the moment the zero crossing occurs. However, for most applications this is surpassed by its main advantages. The magnitude of the event is denoised and amplified by about 20 dB securely stored in a WOM, and if used as direct gate drive, EMC is strongly reduced.

In rare circumstances, it was observed that the voltage crosses from positive to negative without crossing zero. Careful investigation revealed that the value bypassed V=0 by momentarily taking on an imaginary value. This phenomenon is illustrated in Fig.3.

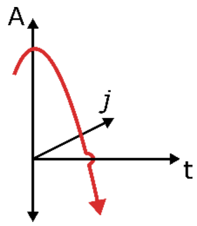

Fig. 3 Signal avoiding zero detection in standard circuits by transitioning via the complex plane

The reference short used to detect the magnitude, which plays a crucial role in identifying zero crossings, was extended by having a +j0 Ohm inductive and a -j0 capacitive short covering all possible zero crossing values.[1] The arrangement is shown in Fig. 1.

IV. Conclusion

With the help of a novel zero crossing quantifier, ZCQ it is possible to precisely capture the amplitude of complex zero crossings. Using this as gate drive information a strong reduction in EMC levels was observed. Further improvements of the circuit will be achieved by merging the state of the art zero crossing timing detector technology with the novel ZCQ to obtain exact timing and magnitude information in one circuit.

V. Acknowledgement

We want to thank Prof. Bernd Deutschmann for having deep in-sight into the dependence of EMC performance on the magnitude of the zero-crossing and encouraging us to focus on closing this significant gap in his EMC understanding.

References

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[1] It was observed that students taking the class “Verbindungstechnik” created the best short circuits we could obtain, allowing us to retain a set of reference shorts.