Synchronous Sampling Device for the Parametric Current Transformer

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Beam current is one of the main parameters of any particle accelerator. Principle of operation of commonly used non-intercepting beam current sensors (current transformers) is based on detection of electromagnetic field produced by the charged moving particles [1]. In case of continuous beam stored in the accelerator very low constant magnetic field has to be measured (e.g. magnetic field carried by 1 mA beam in 10 cm distance is about 1 nT while the Earth magnetic field, for comparison, is as large as 50 µT). Such a small magnetic fields can be measured using so-called fluxgate magnetometer, operation principle of this device is well-known and can be found in Refs. [1, 2]. These devices are widely used for small (up to 10 pT) magnetic fields measurements (instead of Hall and MR sensors) in different fields of science and technology [3, 4].

The Parametric "Current Transformer" (PCT) from Bergoz Instrumentation, installed at COSY, belongs to such type of magnetometers. It construction contsist of two modulation cores and feedback current loop [1]. Despite of all the advantages of the device, a small difference in magnetic properties of two cores leads to undesirable AC component in the feedback current loop and, therefore, in the output signal. Such a ripple with the excitation frequency of 7 kHz can be easily dumped by an analogue filter, which, of course, will decrease band width of the output signal.

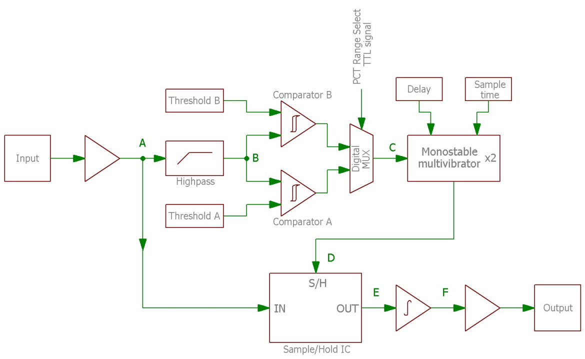

Fig. 1: Block diagram of the synchronous sampling device installed at COSY PCT.

Alternative method to extract DC component from PCT output signal is to read this signal in-phase with excitation frequency. Block diagram of a synchronous sampling system, designed and build to improve PCT performance, is presented in Fig. 1. Locked digital signal for sampling system is generated from the "Full Bandwidth" signal of the current transformer using a high pass filter, to extract the AC component of the signal, which is later fed into a logical comparator. Since amplitude of the ripple in the PCT output signal can differ depending on PCT operation range (0-10 mA or 0-100 mA) two different comparators have been used. Switching between comparators is done using digital multiplexer controlled by the TTL signal generated in PCT electronics to switch operation range. Falling edge of the comparator signal starts the first of two monostable timers connected in serial. The first timer is allows to set sampling delay (0-140 µs), while the second one is used to set sampling gate (8-22 µs), necessary to charge the hold capacitor inside the sampling and hold (SH) chip. This timing scheme drives SH chip which synchronously reads the PCT output signal and holds the value until next period. Phase shift for the output signal can be adjusted using trimmer. On the final stage, ripple from the sample and hold chip is smoothed with a simple RC circuit.

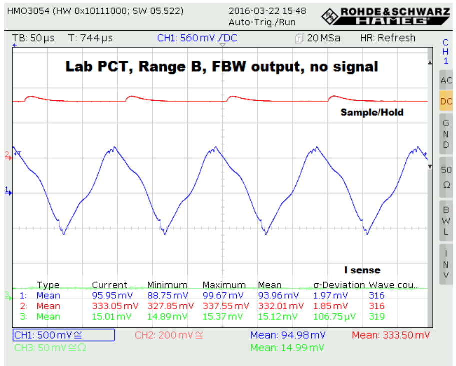

Fig. 2: Laboratory PCT "Full Bandwidth" output waveform (blue) and signal obtained from synchronous sampling device (red).

Due to minor differences between current transformers at COSY and in the laboratory two different devices have been produced. Waveforms obtained with the lab PCT are shown on the Fig. 2. Attenuation of -33 dB for the PCT modulator ripple can be reached using constructed sample and hold system without additional limitations on the output signal bandwidth. Similar kind of attenuation can be reached with the help of first or second order low pass filters with cut off frequencies of 160 and 400 Hz, respectively.

References:

[1] P. Forck, "Lecture Notes on Beam Instrumentation and Diagnostics", 2011, available via `http://www-bd.gsi.de/conf/juas/juas_script.pdf`

[2] K. Oyama and C. Cheng, "An Introduction to Space Instrumentation", (2013), available via `http://www.terrapub.co.jp/onlineproceedings/ste/aisi/`

[3] G. Musmann and Yu. Afanassiev, "Fluxgate Magnetometers for Space Research", 2010.

[4] W. Telford et al., "Applied Geophysics", Cambridge University Press (1990).