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Time of flight measurement by the PH32 chip

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The frontend readout chip PH32 suitable for measurement of X-rays, beta radiation and ions first presented in [1] is primarily dedicated to the dose rate measurement and basic spectroscopy. Present article is focused on the time of flight functionality which was implemented in the new version of the PH32 chip and can be used in various applications as particle tracking or ion mass spectroscopy [2]. The PH32 chip was manufactured using a commercial 180 nm CMOS process and can operate in two operation modes. The first mode, the High Gain Mode (HGM), is suitable for the measurement of the generated charge in the range from about 5 ke⁻ to 70 ke⁻ for soft X-rays and beta radiation. The second, the Low Gain Mode (LGM), is used in the range from about 500 ke⁻ to 7 Me⁻ suitable for alpha particles. The PH32 chip contains 32 identical channels operating individually, which can be connected to the silicon strip sensor by the wire bonding. The chip is optimized to the strip sensor capacitance of 8 pF with the AC coupling. The electronic noise is about 1100 e⁻ for the chip calibration charge of 10 ke⁻ at HGM and about 2300 e⁻ for the chip calibration charge of 2 Me⁻ at LGM. The measurements presented in this paper are focused on the channel response to the injected charge including channel dispersion and time-walk measured with variety of injected charge. Time of flight is derived from an internal oscillator which can be set by internal data to analog converter up to around 333 MHz. Time-stamp is stored in a 16 bit asynchronous counter for every channel separately, which can be read as a shift register from all channels after exposition. The internal oscillator is a significant source of dispersion between channels and between hit occurrences. The variety of sampling frequencies and their influence on the measurement is discussed in this article as well as the effect of equalization of the chip which has to be performed for the proper chip functioning. The PH32 chip contains also a 40 bit synchronous counter designed in STSCL logic which can be used for time of flight measurement triggered by an internal trigger derived from all channels. This method of time of flight measurement can be efficient only for low dose rate, because only the first hit from all channels is detected. However, the chip using this functionality can operate in hit energy measuring mode [1] and time-walk can be corrected. This article presents correlation between time of flight measured from all channels by one 40 bit synchronous counter and energy measurement for every channel separately. Internal trigger used for triggering STSCL logic is also propagated to output for triggering external hardware. The output is realized as proprietary differential signaling to avoid crosstalk between digital output at PCB and wirebonding between sensor and chip. This article compares the results provided by the 40 bit synchronous counter with trigger output and comparison between time of flight measured by individual channel by the 16 bit asynchronous counter with trigger output. The article describes a newly developed frontend readout chip suitable for particle rate measurement, measurement of deposited charge and time of flight.

[1] Janoska, Zdenko, et al. "Measurement of ionizing particles by the PH32 chip." Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2015 IEEE. IEEE, 2015.

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[2] Nomerotski, Andrei, et al. "Characterization of TimepixCam, a fast imager for the time-stamping of optical photons." Journal of Instrumentation 12.01 (2017): C01017.

Author: JANOSKA, Zdenko (Czech Technical University (CZ))

Co-authors: NEUE, Gordon (Czech Technical University (CZ)); TOMASEK, Lukas (Czech Technical University (CZ)); MARCISOVSKA, Maria (Czech Technical University (CZ)); HEJTMANEK, Martin (Czech Technical University (CZ)); MARCISOVSKY, Michal (Czech Technical University (CZ)); HAVRANEK, Miroslav (Czech Tech-

tical University (CZ)); SVIHRA, Peter (Czech Technical University (CZ)); BENKA, Tomas (Czech Technical University (CZ)); VRBA, Vaclav (Czech Technical University (CZ)); KAFKA, Vladimir (Czech Technical University (CZ))

Presenter: JANOSKA, Zdenko (Czech Technical University (CZ))

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