TEST BENCH EXPERIMENTS FOR ENERGY MEASUREMENT AND BEAM LOSS OF ESS-BILBAO

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Abstract

Various test benches have been developed at ESS-Bilbao in order to characterize different beam diagnostics and control systems prior to their installation on various parts of the accelerator. One test bench includes time-of-flight (TOF) characterization for energy measurement using fast current transformers (FCT). Using FCTs for the TOF measurement would allow us to measure accurately the delay between two successive bunched or un-bunched beam pulses of low energy ions (Figs. 1,2). The other test bench includes a beam loss monitoring and interlock system using ACCTs, cRIO and PXI chassis with some acquisition modules and optical fiber link which represent a complete system of beam loss detection, interlock logic and trigger signal transmission. Having an integration on the ACCT output also allows us to measure the beam charge at the location of monitoring. In the test benches the functionality of hardware and software, the logic and required signal specifications like rise time, jitters and delays are measured. An overview of test benches and their measurement results are reported in this paper.

ENERGY MEASUREMENT

Time-of-Flight (TOF)

Measurement of the velocity of a non-relativistic particle is related to kinetic energy W as:

$$W = m(\beta c)^2 / 2$$

$$\frac{\Delta W}{W} = 2\frac{\Delta \beta}{\beta}$$

The velocity is measured by Time-of-Flight tf of a beam bunch over a known distance L. The distance in out test bench was measured by means of two synchronized Fast Current Transformers (FCTs).

The accuracy of the measurement can be expressed within the equation:

$$\frac{\Delta \beta}{\beta} = \sqrt{\left(\frac{\Delta L}{L}\right)^2 + \left(\frac{\Delta t}{t_f}\right)^2}$$

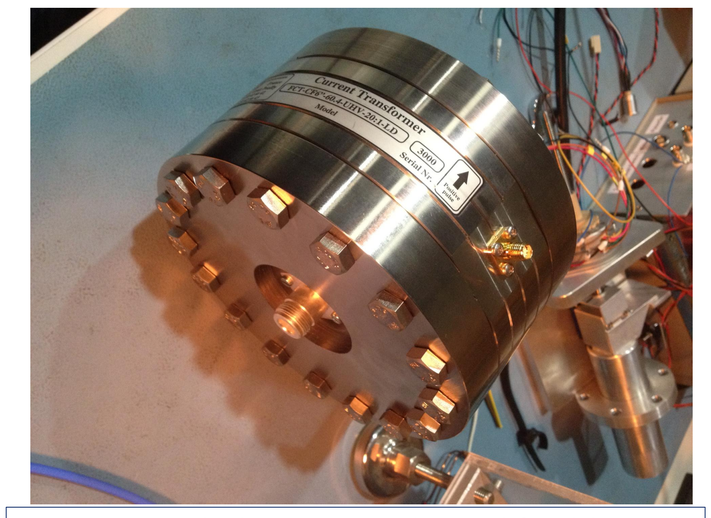

Fig.1: FCT with the cover and signal feedthrough

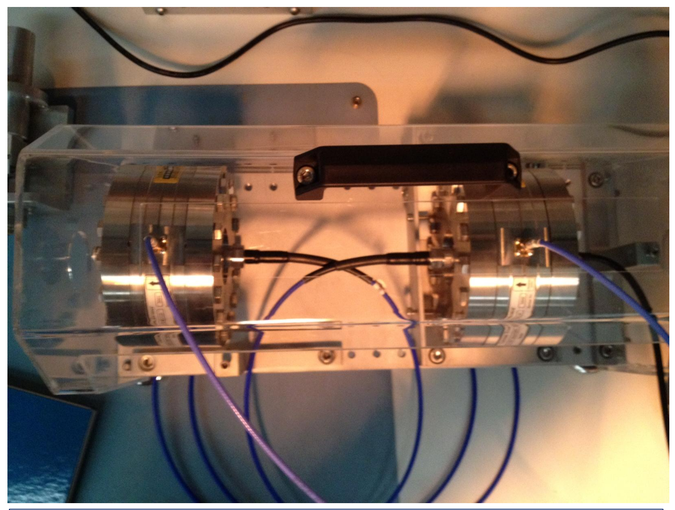

Fig. 2: Two FCTs assembled on the test bench

BEAM LOSS MONITORING

Two ACCTs are used as the front-end detectors of the beam current. The beam current loss between ACCT1 and ACCT2 is carried out by means of R1 and R2. R1 is a fixed resistor of 100 Ω, while R2 is a potentiometer ranging from 1 Ω to 3 kΩ. After amplification and noise filtering, the signal from ACCTs are fed to PXI-7852R NI card [5]. The card is programmed for acquisition and logic generator of the interlock signal. Due to the development in low energy beam pulse from ACCT1 to ACCT2, the two signals are integrated over a time duration of pulse width (or if necessary a shorter interval) rather than directly used for amplitude comparison. The interlock master is a cRIO chassis with realtime controller cRIO-9024 [6]. cRIO would make the acquisition and performs calculation or logic in order to generate the global interlock signal with the NI-9402 card. In the current test bench, except the interlock signal from PXI-ACCT no other interlock is fed to the cRIO.

Various signals as the input signal and output interlock are shown in Fig. 5. The green colour signal is the output local interlock from PXI. This signal will produce a global interlock in the cRIO output, which is then converted to optical signal with the EO. The optical signal is transmitted through a 30m optical fiber and, at the end, converted back to electrical signal in the OE (purple colour signal). The delay between rising edge of interlock and falling edge of EO shows a time duration of 400ns which includes the time required for the cRIO acquisition, logic execution within cRIO, EO conversion, transmission via a 30m optical fiber and OE conversion.

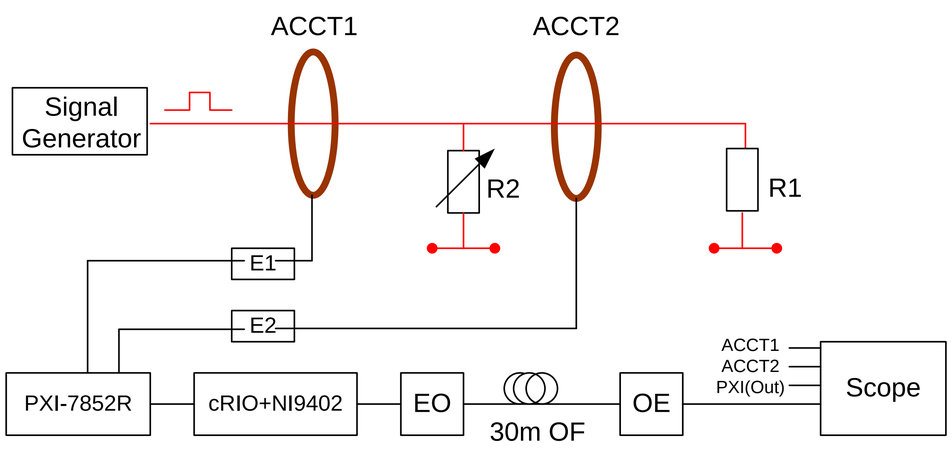

Fig.6: BLM test bench scheme

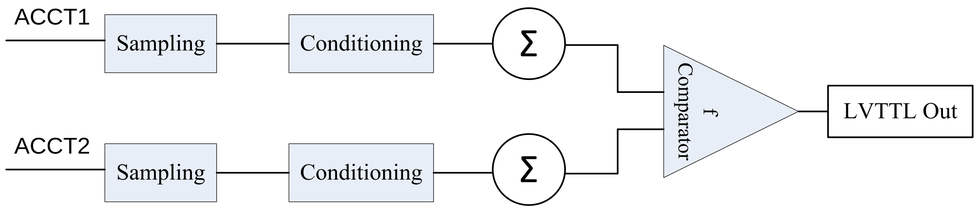

Fig. 7: PXI FPGA simplified logic diagram

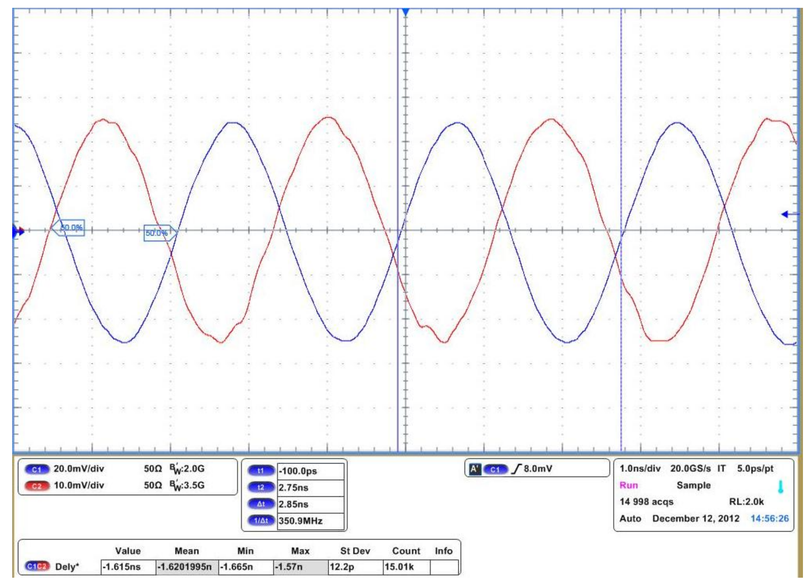

Fig. 3: For a beam signal with bunch frequency of 352 MHz and current of 72 mA and 12 mA, the rms jitter was 8 ps and 17 ps accordingly. The mean energy accuracy for a beam current of 40 mA and 352 MHz was 0.1%.

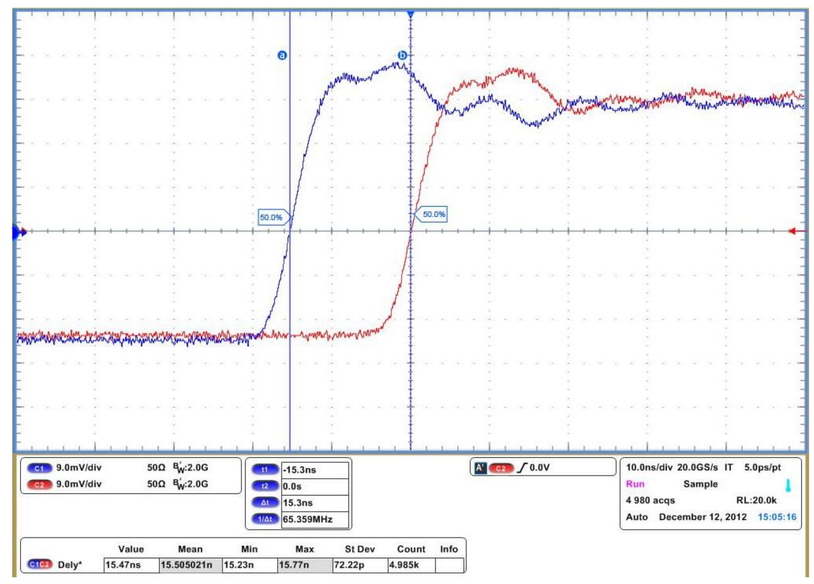

Fig. 4: The un-bunched pulse measurement results show the rms delay jitter of TOF gets higher with the decrease in pulse current amplitude. For the current of 80 mA and 10 mA, the rms jitter of 85 ps and 130 ps were observed accordingly. The mean energy accuracy for a beam current of 40 mA was smaller than 0.5%.

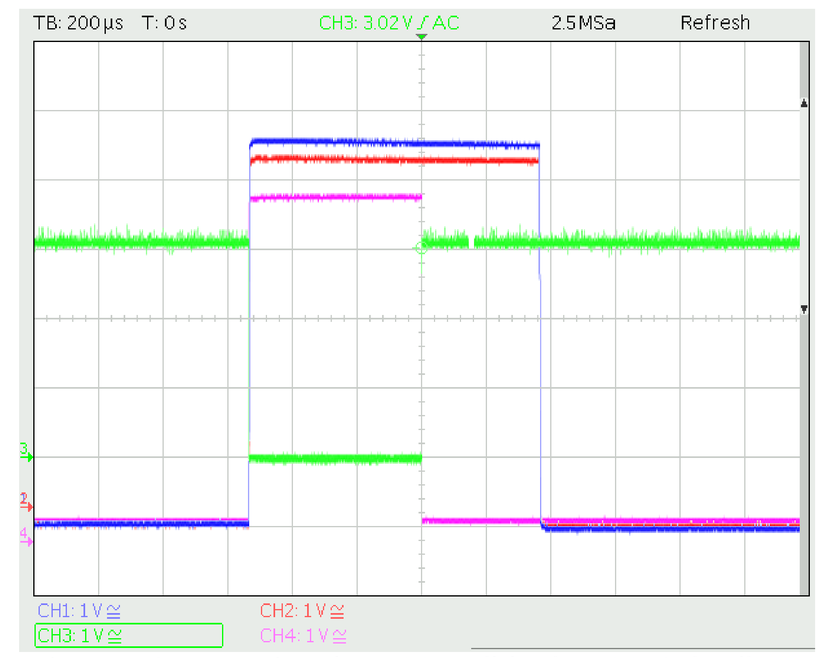

Fig. 5: Output signals, ACCT1 (blue), ACCT2 (red), PXI-Out (green) and OE (purple). The number of samples in this specific measurement was 225 samples (450 µs). The overall delay is measured to be 540 µs, which after deduction of 450 µs of sample real time acquisition, provides 90 µs time consumption for interlock activation. The measured rms jitter on the output signal was 450 ns.