Measuring Beam Intensity and Lifetime in BESSY II [1]

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Abstract

The measurement of the intensity of the beam in the transfer lines and the storage ring are based on current transformers. The pulsed current in the transfer lines is measured with passive Integrating Beam Current Transformers (ICT). The bunch charge is transferred to a DC-voltage and sampled with a multifunction I/O-board of a PC. The beam current of the storage ring is measured with a high precision Parametric Current Transformer (PCT) and sampled by a high quality digital volt meter (DVM). A stand alone PC is used for synchronisation, real-time data acquisition and signal processing.
Current and lifetime data are updated every second and send via CAN- bus to the BESSY II control system. All PC programs are written in LabVIEW.

1 INTRODUCTION

BESSY II started operation as a third generation synchrotron radiation light source at the beginning of this year. The facility consists of the 1.7 GeV electron storage ring and the full energy injection system comprised of the synchrotron cycled at 10 Hz and a 50 MeV microtron as a pre-injector [1]. Along the chain of accelerators and transfer-lines different types of current monitoring devices are employed and have to fulfil the following requirements: measurement of the intensity of the pulsed beams in the two transfer lines, the accurate determination of the intensity of the accelerated beam in the synchrotron, and the high precision current measurement of the stored beam in the ring. All measurements had to be performed in real-time and have to be updated every second in order to allow for the fast and accurate extraction of the injection efficiency and the lifetime of the beam. In addition to these measurements and the determination of related parameters, the system had to supply trigger and timing signals for the beam position monitor (BPM) system running in the single turn mode [2]. In this system 4 shots and the corresponding injected beam intensities are required to determine the position of the beam as accurately as possible. This is achieved by current normalising the 4 data sets. As a solution a stand-alone hardware triggered solution based on a PC running under LabVIEW was chosen and the system has been realised with commercially available components.

2 HARDWARE

The current transformers were manufactured by BERGOZ [3, 4]. In the transfer lines the sensors are mounted over a short insulated piece of vacuum pipe and shielded by an aluminium cover. In the storage ring and in the synchrotron the installation of the DC current transformer (DCCT) has been realised with more care in order to prevent RF fields of the electron beam leaking to the sensor's head and heating it up. In addition onion-like thin soft iron sheets shield the sensor from magnetic stray fields created by nearby magnets. The vacuum chamber for the DCCT is based on the SLAC B-Factory design[5].

The layout of the beam current monitor system is shown in Fig. 1. The stand alone industry PC has been equipped with three additional boards. The first is a multifunction input/output-board AT MIO-16X from National Instruments. This board in combination with additional external trigger electronics creates all the required timing signals for the DVM, the synchronisation of the pulsed beam intensity measurements, and synchronises the single turn beam position measurements with the intensity measurements. The multiplexed 16 bit ADC on the multifunction board is used for the acquisition of the signals delivered by the ICTs. The digital outputs of the board are used to switch the external electronics to the desired modes of operation. The second board is the GPIB interface required for the communication to the high precision DVM HP3458A from Hewlett Packard which measures the current of the stored beam.

Signal processing is performed in the following way: The microtron delivers pulses of approximately 1 µs duration and the bunch train extracted from the synchrotron has a length of 360 ns. Every 100 ms the charge passing through the transfer lines is detected by the ICT. Over a certain amount of time the beam charge monitor integrates the signal and produces a constant output voltage which is finally sampled by the multifunction I/O-board. With the sampling rate of 100kS/s of the ADC a 15 time over-sampling of each channel is obtained.

The beam current of the storage ring is measured with a high precision (PCT) and sampled by the DVM. The intensity of the beam accelerated in the synchrotron can

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be digitised through one of the additional ADC channels of the multifunction board. Currently the DC-signal is displayed on a scope in the control room only.
The correct timing of the measurements is realized through the trigger generator which is connected to the accelerator timing system. Inputs are the injection times into the synchrotron and into the storage ring and the revolution frequency of the storage ring for the BPM system.

The communication between the intensity monitor and the central BESSY II control system is realized with a third interface card and through the CAN bus. The PC together with the electronics is mounted in a 19’’ rack in the storage ring hall close to the current transformers.

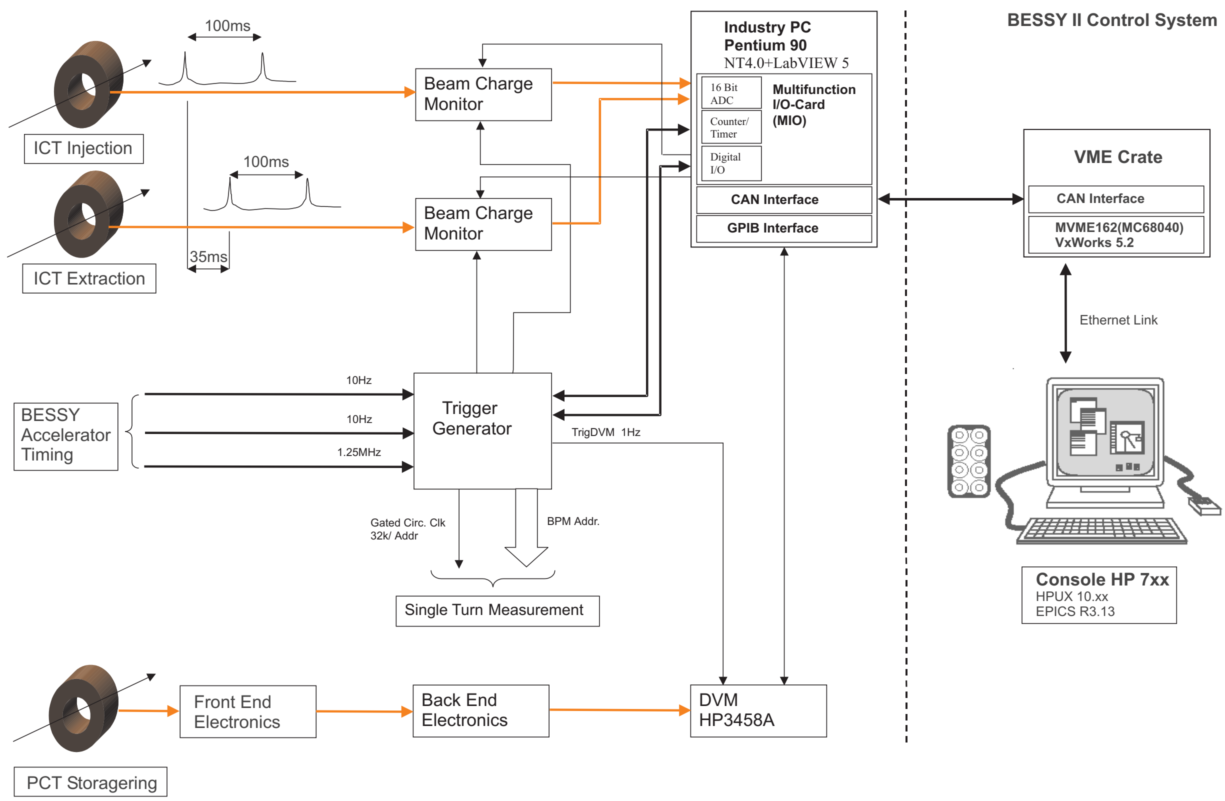

Figure 1: Hardware of the BESSY II beam current measurement system

3 SOFTWARE

The software has to fulfil these requirements:

- Continuous acquisition of the intensities in the transfer lines.
- Measurement of the storage ring current with high precision every second and the calculation of the lifetime from the decay of the intensity over the last 10, 50 and 100 seconds.
- Determination of the injection efficiency.
- Preparation of the results and communication through the CAN bus to the control system with an update rate of 1 per second.
- Synchronization of the BPMs in the single turn mode.

The required real-time operation of the system with all the feature mentioned above was difficult to realize within the BESSY II control system concept which is based on Epics, VxWorks, and the non-deterministic Ethernet. A stand-alone Pentium PC has been chosen as a solution which is running under Windows NT4 and Labview5. LabVIEW is a multitasking system that can run multiple programs in multiple threats. So we could realize the required real-time data acquisition system under the operation system Windows NT4. The program structure is shown in Fig. 2.
The whole system had to be designed in such a way that no special start-up procedure is required. After a power fail the operating system of the PC, the measuring process, the data analysis and the communication to the central control system start automatically.

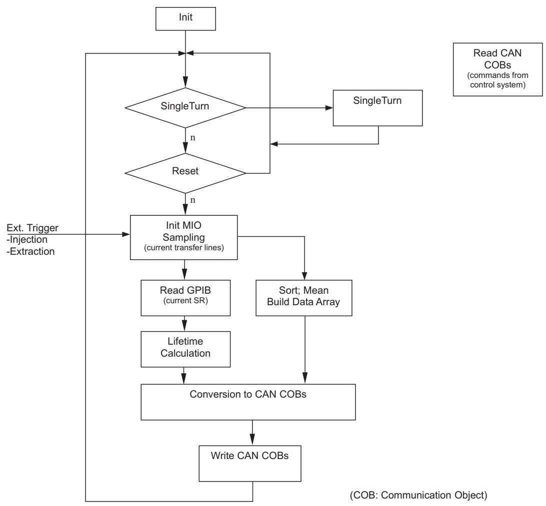

Figure 2: Program structure of data acquisition system

4 MEASUREMENT RESULTS

This beam current measurement system is in operation continuously and without any failure since the beginning of the commissioning in April 1998.

The measurements in the transfer channels are disturbed by high noise levels predominantly created by the pulsed kicker and septa magnets and the pulse forming networks of the microtron. Better signals have been obtained by signal amplification with a 24 dB low noise pre-amplifier very close to the sensor heads and low pass filters in the signal chain. Typical signals are shown in Fig. 3 and 4. Even though the signal-to-noise ratio was not large, these signals and the actual current accelerated in the synchrotron are very helpful in the daily optimization process. In order to achieve an accuracy for the intensities in the injector of better than 1 percent further improvements are required.

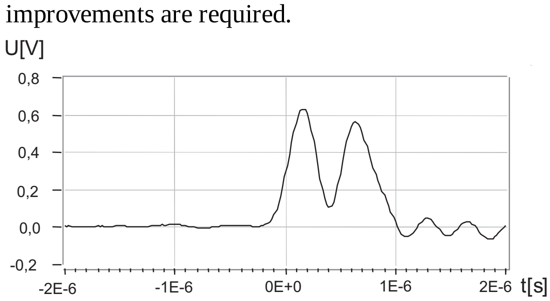

Figure 3: Typical current pulse delivered by the microtron (first pulse 6.5mA/ 550ns)

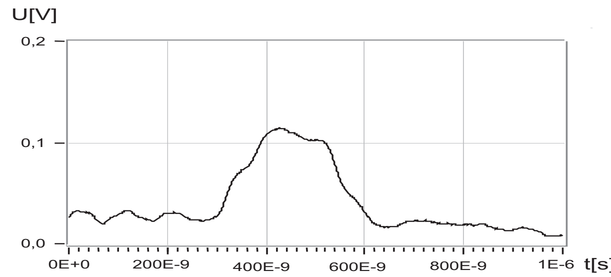

Figure 4: Typical signal of the beam extracted from the synchrotron (1mA/ 300ns)

In the storage ring the beam lifetime is still dominated by the vacuum pressure because the vacuum system had to be opened on several occasions for completing machine elements and user front-ends. Consequently, photon desorption is still the dominant process in reducing the vacuum pressure and the lifetime [6]. Fig. 5 displays the lifetime at 20 and 100 mA. Each time the vacuum system was broken the integrated dose curve was reset. The graph displays logged lifetime data [1].

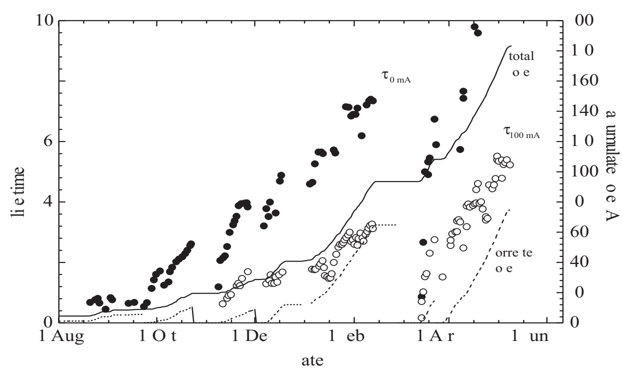

Figure 5: Lifetime at 20mA (solid dots) and 100mA (open dots) and accumulated dose (curve) versus time

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