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# A TURN-BY-TURN, BUNCH-BY-BUNCH DIAGNOSTICS SYSTEM FOR THE PEP-II TRANSVERSE FEEDBACK SYSTEMS*

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## *Abstract*

A diagnostics system centered around commercial fast 8-bit digitizer boards has been implemented for the transverse feedback systems at PEP-II. The boards can accumulate bunch-by-bunch position data for 4800 turns (35 ms) in the *x* plane and the *y* plane. A dedicated trigger chassis allows to trigger the data acquisition on demand, or on an injection shot to diagnose injection problems, and provides gating signals for grow-damp measurements. Usually, the boards constantly acquire data and a beam abort stops data acquitision, thus preserving the last 4800 turns of position information before a beam abort. Software in a local PC reads out the boards and transfers data to a fileserver. Matlab-based data analysis software allows to present the raw data but also higher-level functions like spectra, modal analysis, spectrograms and others. The system has been instrumental in diagnosing beam instabilities in PEP. This paper will describe the architecture of the system and its applications.


## INTRODUCTION

At PEP-II[1] we repeatedly face the need to analyse beam-abort data *post-hoc* to find out why the beams got lost and how to prevent similar beam aborts. While there are good fault files preserving the state of the rf system[2] only limited abort files with transverse data are gathered by the BPM system.[3] In particular, only a few bunches can be monitored at any given time. A second need is the ability to perform grow-damp measurements by briefly opening the feedback path and closing it again before the transverse beam motion has become too large to be damped again by the amplifiers.

## HARDWARE

The transverse bunch-by-bunch feedback system by its nature has the information for every bunch and is therefore the location to add such diagnostic capability. In order to get a system up and running in about a month time frame, commercially available digitizers and scopes were evaluated. The GaGe CompuScope 82G board[4]—a fast 8-bit digitizer board for the PCI bus—met all the requirements and was available with a 4 week lead time. The 82G samples at up to 1 GHz frequency and has about 400 MHz analog bandwidth, both fast enough for the 238 MHz bunch frequency at PEP-II. The board has two channels with up to 8 MB buffer space for each channel, which we assigned to the *x* and *y* plane, resp. In this way, two boards in the same PC let us acquire data from both planes in each ring. Fig. 1 shows an overview of the transverse feedback system with the addition of the data acquisition. The initial system

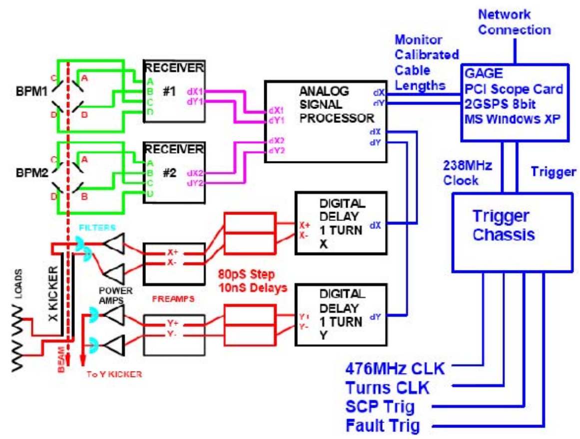


Figure 1: PEP-II TFB system with the added data acquisition facilities.

used the GaGeScope software and captured first data on the last day of the 2004 run.

The GaGe 82G boards require an external, stable, 238 MHz clock source to be in phase with the bunches. The 476 MHz rf reference used for the rf and feedback systems is divided by 2 with a PECL divider to generate the 238 MHz clock for the boards. The divider is reset every PEP turn using an LER turns-trigger from the control system, see Fig. 2. This prevents the divider from coming up 180° out of phase, shifted by a 476 MHz bucket. If this were to happen the digitizers would clock-in data between the bunches rather than on the bunches.

There are several different ways of triggering the 82G

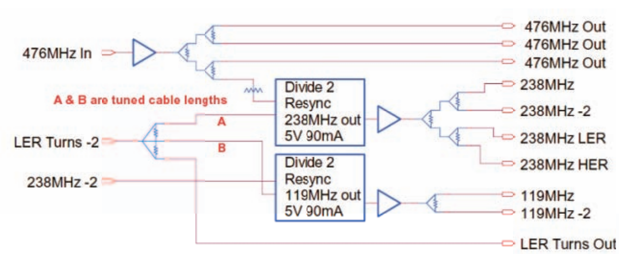


Figure 2: Timing logic for the GaGe-82G cards.

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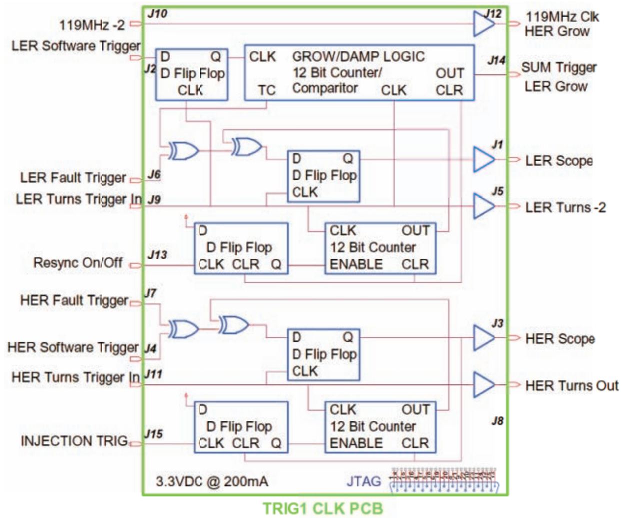


Figure 3: Trigger logic implemented in the CPLD.

boards. They can be triggered by a beam abort signal, a digital output from the control system, or an injection trigger. All of these inputs along with turns-trigger inputs from the control system are used to generate for the 82G boards an output trigger which is synchronous with the ring turn. This allows collected data to always start with the same bucket in the ring. The logic is implemented in a field-programmable device (CPLD) from Xilinx[5]. The chip also contains the logic and timing for the grow-damp measurements, which involve opening the feedback loop for a brief time (0.94 ms…15 ms) and closing it again and recording the resulting growth and damping of coherent motion. A block diagram of the implemented logic is shown in Fig. 3, physically it resides in the timing chassis as well.

A data transfer program on the PC reads out the card after a trigger. The data files (2 per card) get stored locally in a watch folder, to be transferred to a central fileserver via NFS by a second program. The files are also locally archived.

## TFBGUI

In order to maximize usefulness of the data, an analysis and presentation program has been written in Matlab. This program presents the user with a simple GUI to pick the data file and the desired plot. The data analysis routines follow the algorithms described in [6].

Fig. 4 show a basic 3-d plot of every $2^{nd}$ bunch and every $2^{nd}$ turn and the transverse position along the vertical axis. In this example one can see how parts of the beam become unstable and eventually the whole beam oscillates but with different amplitudes along the train. The transient along the bunch train is an artifact arising from the phase transient due to the gap in the beam and not a real orbit excursion. The program allows then to plot data for individual turns or bunches to get a more detailed picture of the motion.

Of interest in such a case is the nature of the instability, *i.e.* which plane dominates the motion (due to dispersion and residual coupling it is not always evident which plane goes unstable). Fig. 5 shows the frequency analysis of one particular groups of bunches of the data shown in Fig. 4. Relatively strong lines at about 4 kHz in both spectra in-

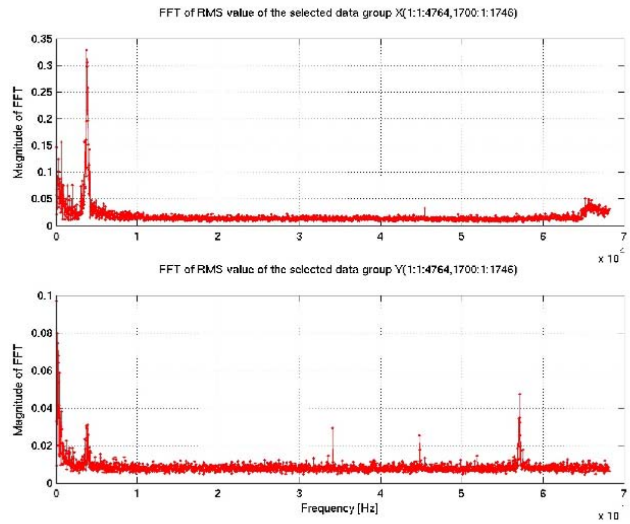


Figure 5: Frequency spectrum of the data shown in Fig. 4. The top trace is the horizontal motion, the bottom trace, vertical.

dicate the motion is dominated by longitudinal oscillation, although there is also a line 56…57 kHz in the vertical spectrum. To further analyze the motion a modal analysis can be done against time and is shown in Fig. 6. The fastest

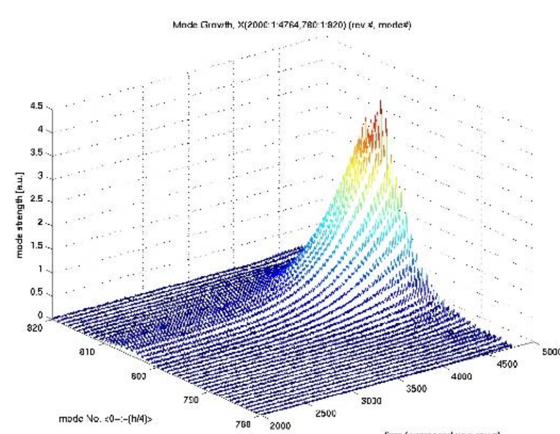


Figure 6: Modal spectrum of the data in Fig. 4. Only modes from 700 to 820 are shown.

growing modes are a cluster around mode 805. On the basis of such analysis one would then make a decision to, *e.g.* investigate the tuning of the longitudinal feedback system, which normally damps these modes. The growth rate itself for a given mode can be fitted with an exponential to, in this case, yield a growth rate of about .25 $ms^{-1}$.

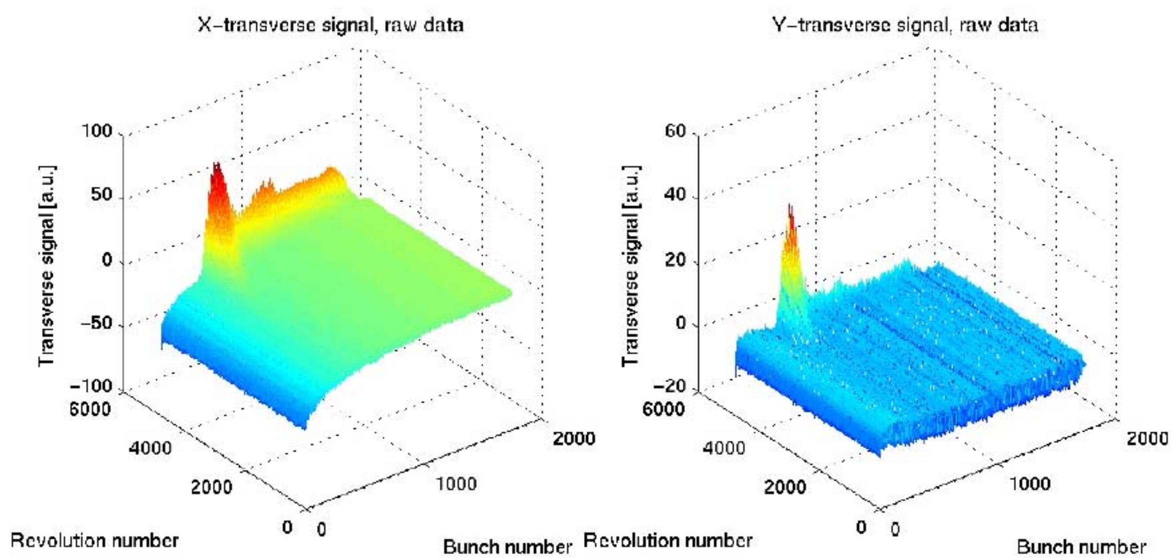


Figure 4: 3d plot of the transverse beam position.

The grow-damp capabilities of the hardware are complemented by the analysis in the software, allowing to extract growth rates and damping rates. A recent example for the HER vertical plane is shown in Fig. 7, together with exponential fits to the growing and damping parts of the motion.

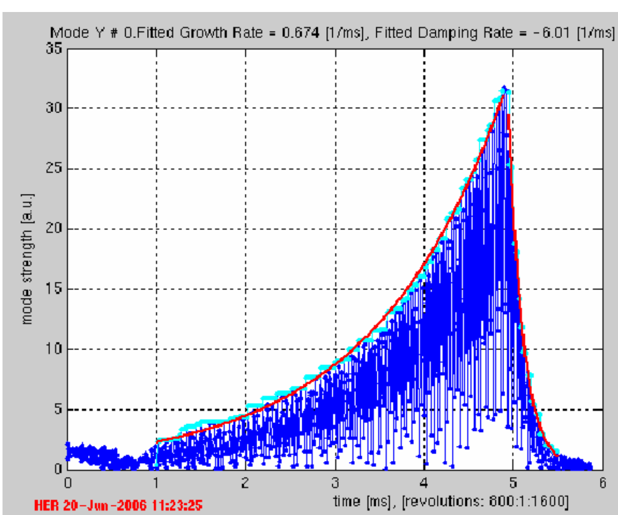


Figure 7: Grow-damp data for the HER, *y* plane, at 1700 mA.

Other facilities include the possibility of plotting the spectra for each bunch in a 3-d plot as well as plotting a "spectrogram" of tunes *vs.* turn number, an example for the latter can be found in [7].

## CONCLUSION

The data acquisition system and its associated "TFBgui" software have quickly become an indispensable tool for trouble shooting beam aborts in PEP-II. They played a significant role in identification and classification of several kinds of beam aborts that turned out to be induced by discharges in the vacuum system[7]. A recent addition is in form of a 3$^{rd}$ board used to acquire the bunch charges.

## REFERENCES

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