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Operation and Performance of the PEP-II Prototype Longitudinal Damping System at the ALS*

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Abstract

A modular programmable longitudinal feedback system has been developed as a component of the PEP-II R+D program. This system is based on a family of VME and VXI packaged signal processing functions which implement a general purpose digital feedback controller for accelerators with bunch spacings of 2 ns. A complete PEP-II prototype system has been configured and installed for use at the LBL Advanced Light Source. The system configuration used for tests at the ALS is described and results are presented showing the action of the feedback system. Open and closed loop results showing the detection and calculation of feedback signals from bunch motion are presented and the system is shown to damp coupled-bunch instabilities in the ALS. Use of the system for accelerator diagnostics is illustrated via measurement of grow-damp transients which quantify growth rates without feedback, damping rates with feedback, and identify unstable modes.

1. PEP-II Longitudinal Prototype

The PEP-II longitudinal prototype is a modular bunch-by-bunch processing system designed to implement longitudinal feedback signal processing [1]. The system is composed of several processing modules in VME and VXI formats. The analog-to-digital and digital-to-analog functions are implemented in a pair of VXI processing modules which are capable of sampling bunch motion and generating correction signals at a 500 MHz rate, which allows the system to operate with bunch spacings of 2 ns. The 500 MHz A/D functions are incorporated in the Downsampler module, which is a programmable sequencer capable of controlling the sampling of up to 2048 bunches with downsampling factors up to 32. The 500 MHz D/A is contained in the hold buffer VXI module, whose buffer memory contains the most recent kick value for each bunch in the system. A VXI packaged QPSK modulator (which generates a kicker carrier signal which spans 1 to 1.25 GHz) and a Timing module (which generates several ECL clock signals from the ring RF master oscillator) complete the digital signal processing VXI modules [2].

The signal processing algorithms are implemented as programs coded on AT+T DSP 1610 microprocessors. These single-chip 16 bit processors are organized into groups of four, with four processors on each VME packaged DSP module. A system configuration for a particular accelerator requires 3 to 20 of the DSP modules, depending on the machine synchrotron frequency, revolution frequency and number of bunches. Each sampling interval the Downsampler module sends bunch data to a particular DSP board (based on the downsampler program) and the DSP board sends computed results to the Hold buffer module. Figure 1 is a photograph of the system configured for testing at the ALS, which uses 10 DSP modules total.The system is configured and downloaded via a set of control programs which specify the operating configuration of the system and generate coefficients for the DSP algorithms. An EPICS based user interface allows a single control interface from a master workstation, which communicates with several commercial VXI/VME processor modules which act to control the VME and VXI bus systems [3].

The analog and microwave components of the system are the same as implemented for the Longitudinal Quick Prototype. The processing bandwidth of the system can be seen in figure 2, which shows an oscilloscope record of the baseband correction signal (updated at the 500 MHz bunch crossing rate) and the resulting kicker drive signal. The risetime of the baseband signal is seen to be 320 ps.

2. ALS Results

A complete 4 processor feedback system (the longitudinal Quick Prototype) has been installed at the ALS since September 1993 [4]. It has been used to develop feedback algorithms and accelerator diagnostics, and is capable of controlling up to 90 bunches in the ALS machine. During the past six months this system has been used with a wideband longitudinal kicker structure and a 200 watt TWT power amplifier for a series of feedback tests and system development [5].

The system has been operated in conjunction with the transverse feedback system successfully for storage ring currents up to 320 mA [6]. The operation of the longitudinal system has been shown to increase the intensity of emitted undulator radiation by a factor of 2.5 (figure 3).

One of the attractive features of the programmable DSP architecture is the flexibility of the system. Because the signal processing is determined by software programs, it is easy to implement many accelerator diagnostic and machine physics measurements in the feedback processing. An example of an instability growth rate measurement is illustrated in figure 4. This grow-damp transient measurement is made by a DSP program which can turn off the longitudinal feedback output of

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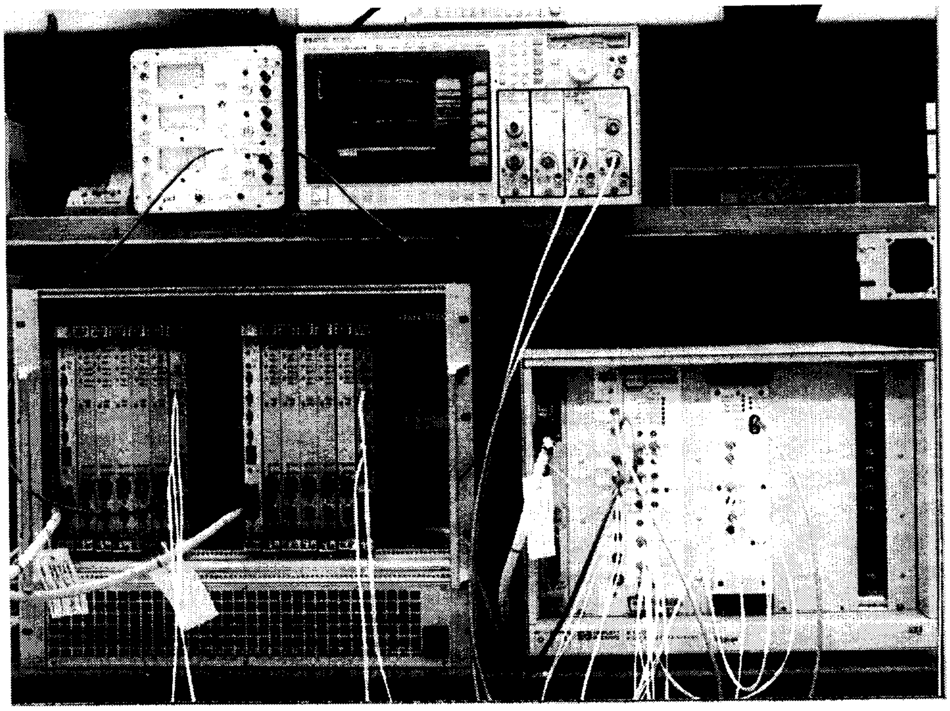

Figure 1. Photograph of the assembled system. The VME crate contains ten DSP modules, while the VXI crate contains the 500 MS/sec Downsampler and Hold Buffer Modules

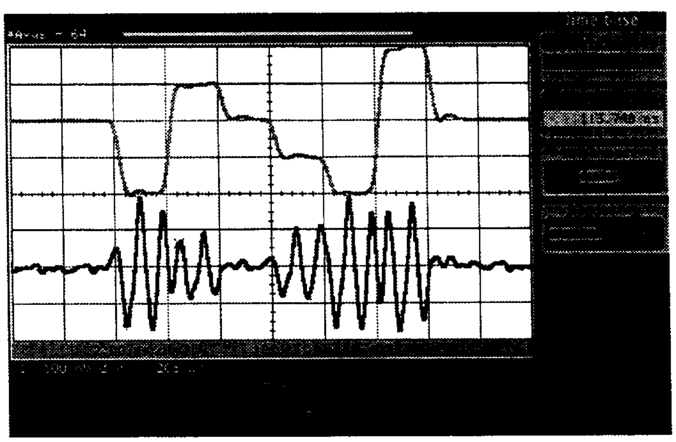

Figure 2. Oscilloscope photo of the baseband correction signal and the resulting amplitude modulated QPSK signal. Signals for 6 consecutive bunches are shown for 2 ns bunch spacing (2 ns/div scope speed). Note the 1 - 1.25 GHz kicker signal phase inverts for the negative correction values.

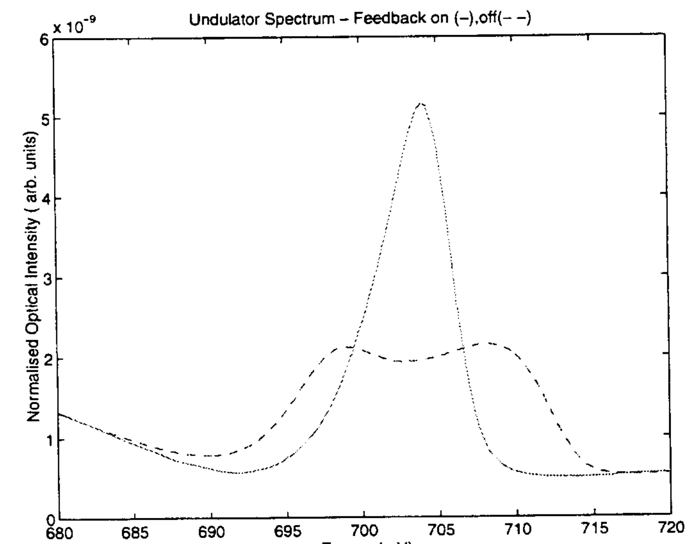

Figure 3. Undulator output spectrum taken at the ALS. The action of the feedback system reduces the linewidth and increases the intensity of the emitted radiation.

selected bunches for a user-programmed interval, and then restore control by turning the output signals back on. During this transient the DSP processors store the oscillation coordinates of the bunches. The transient begins from the stabilized state and reveals the growth rate of an instability via the structure of the envelope of the synchrotron oscillations. The damping rate provided by the feedback system is seen in the second portion of the envelope. The figure shows the motion of a single bunch (out of 40). By examining the envelopes of all the

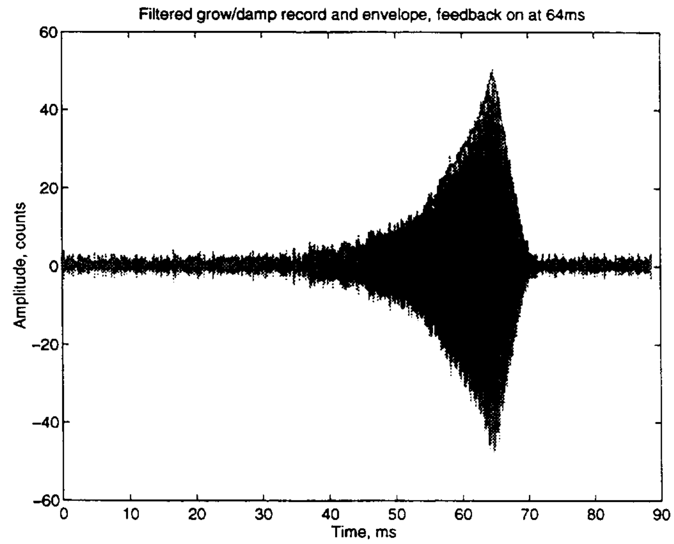

Figure 4. Grow-Damp Transient showing the growth of unstable motion when the feedback is turned off, followed by damping when the feedback is turned back on. The damping rate is seen to be -1.6 ms, while the growth rate is 9.8 ms.

bunches it is possible to identify one or several coupled bunch modes which are unstable.

This growth rate measurement can be made for various accelerator parameters. Figure 5 shows such growth rates as a function of current for several fill patterns and RF cavity tunings in the ALS. Note the linear scaling of inverse growth rate with current (as would be expected from theoretical considerations). Also note the sensitivity of the growth rate to cavity temperature. These measurements allow the feedback system effectiveness to be quantified and the selection of an accelerator operating point to be made. Such trade-offs are very significant in determining the required output power of the feedback system.

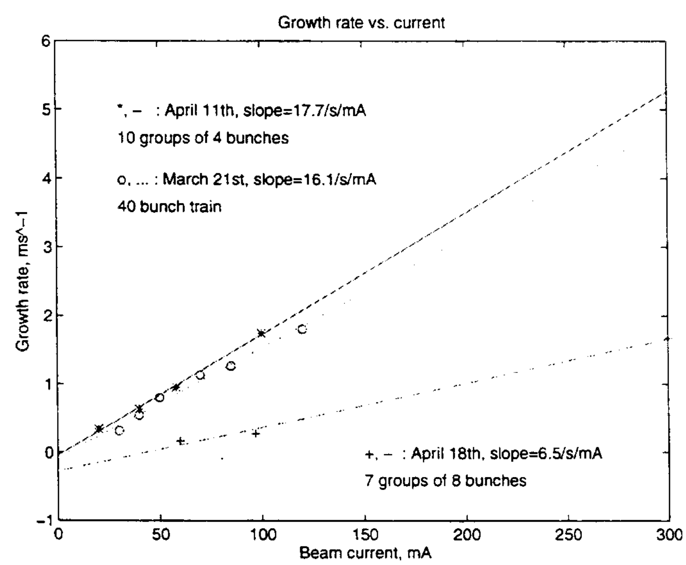

Figure 5. Figure of growth rate vs. current for various fill patterns and cavity temperature at the ALS.

3. SUMMARY

A general purpose digital signal processing system has been developed to control longitudinal multi-bunch instabilities. The system is flexible and operates at sampling rates up to 500 MHz. The operation of the downsampled processing system has been demonstrated at the Advanced Light Source and has been used to control longitudinal instabilities at operating currents up to 320 mA. Ongoing system development of operational software and measurement techniques is continuing, and the prototype PEP-II system will be commissioned for routine ALS operations in 1995.

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