PERFORMANCE AND FEATURES OF THE DIAMOND TMBF SYSTEM

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Abstract

The Diamond Transverse Multibunch Feedback System (TMBF) comprises an in-house designed and built analogue frontend to select and condition the position signals for each bunch. This is combined with the Libera Bunch-by-Bunch system to digitise the signal and perform the relevant calculations before driving the output stripline kickers. As the electronics are based on an FPGA this has allowed us to implement several features in addition to the basic feedback calculations. We report on improvements to both the analogue and digital parts of the TMBF system, along with recent achievements in using the system for instability mode stabilisation and for tune measurement. Also we discuss the potential of the system and additional functionality we plan on introducing in the near future.

INTRODUCTION

The general setup of the TMBF at Diamond has previously been discussed [1]. In the meantime, a number of changes have been implemented, most significantly the harmonic which the frontend receives has been changed to the third. It turned out that the previously chosen fourth harmonic interferes with transverse modes in the BPM block, undermining the pickup of the bunch position. The whole TMBF system has since been fully commissioned and is now ready for operation.

In this paper we report on characterisation of the TMBF system using grow/damp experiments to assess the damping capabilities and additional features in the FPGA code which add various diagnostics functions.

PERFORMANCE

To characterise the TMBF system, and in common with other machines [2][3], we excited each individual mode for a few tens of turns, then started the feedback in order to measure the damping times. This measurement sequence is executed entirely under control of FPGA internal timers which select either the sinusoid excitation signal or the feedback filter for output to the DAC. Figure 1 shows an example of such a measurement. The amplitude of the excited mode is retrieved using an SVD. Following that, the exponential decay can be fitted, which gives the damping time in turns. By repeating this measurement for many modes it was possible to fully characterise the damping capabilities of the TMBF system. This is shown in figure 2.

In our normal operating condition with -6dB filter gain we have thus damping times of less than 100 turns for all

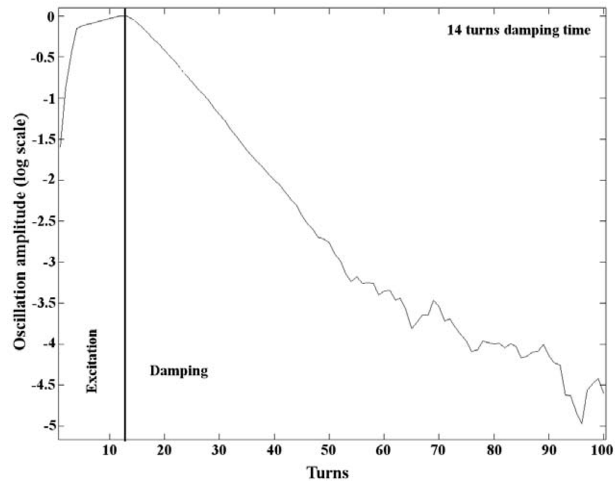

Figure 1: Damping time for mode 10 in the vertical plane

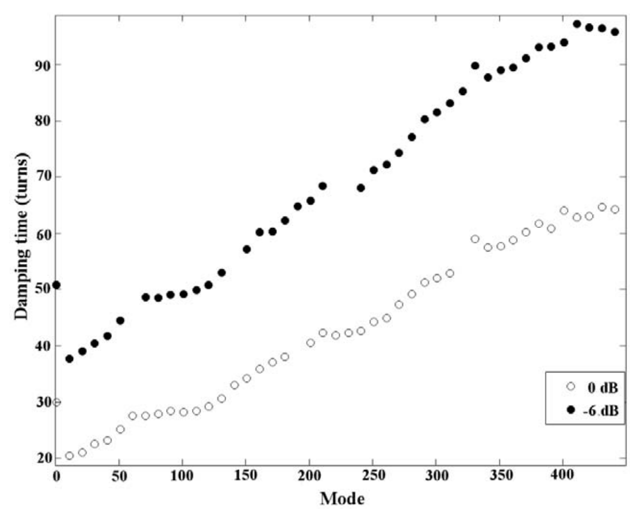

Figure 2: Damping times for all instability modes in the horizontal plane

possible instability modes. By increasing the filter gain to 0dB this can be further reduced to ∼65 turns, at the expense of a narrower margin on the settings for feedback phase and a higher sensitivity to changes in tune frequencies.

By using the TMBF system as a measurement device we have identified the dominant growth modes and growth times of those modes in both planes at 175mA beam current with $\frac{2}{3}$ fill and chromaticity in both planes set to 0.

By switching off feedback and measuring for 3000 turns, the growth rate could be calculated from a straight line fit of the log of the rising curve. Figure 3 shows a typical growth time measurement.

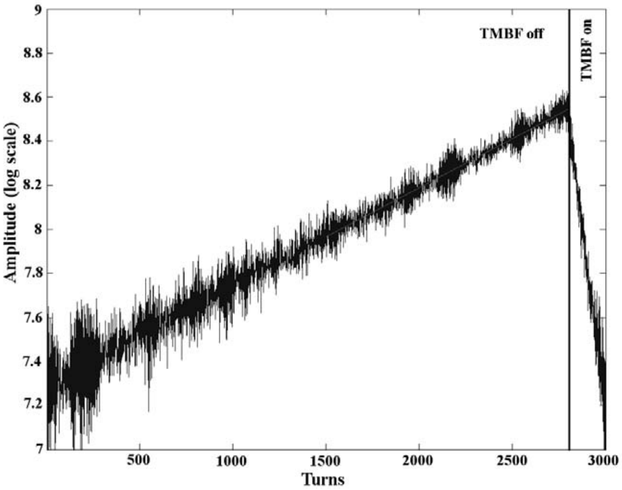

Figure 3: Growth time of the dominant mode in the horizontal plane. Measured at 170mA and 0 chromaticity in both planes

The results from these tests showed that mode 27 is dominant in the vertical plane with mode 1 being dominant in the horizontal plane. The rise times are 625 turns and 2244 turns respectively, meaning that they will be easily stabilised by the feedback. Even for higher beam currents there is enough margin available to suppress instabilities.

In order to further explore the capabilities of the TMBF system, we ran the machine at differing negative chromaticity settings. Decreasing the chromaticity has the effect of making the beam more sensitive to instabilities. The system has proven to be effective at stabilising the beam in both planes down to chromaticities of -27 in the horizontal and -10 in the vertical, with a $\frac{2}{3}$ fill at 60mA. Further experiments are planned in order to more fully determine the performance limits of the TMBF.

ADDITIONAL FEATURES

As the electronics are based on an FPGA, this has allowed us to implement several functions in addition to the basic feedback loop.

By combining FPGA based functionality to control bunch excitation and I,Q detection with control code running on the onboard computer chip we have implemented a 'continuous' tune measurement to allow tune tracking.

Figure 4 shows a schematic of the FPGA code. The I and Q signals are generated by mixing the incoming signal with the sine and cosine output of an oscillator. The oscillator can sweep between 0 and 250 MHz, however we sweep just in a range of $\pm$26kHz around the betatron tune frequencies. The system is set to hold for $\approx 5\mu$s at each sweep point while each accumulator takes 25000 data points and outputs one data value per sweep point. The output of the accumulators is then stored into two buffers to generate the I and Q waveforms for later retrieval. Once per second the control code takes the values stored in the I and Q buffers and adds them in quadrature in order to get the tune spectrum (see figure 5). The position of the peak of this spectrum gives the tune value which is passed out to the machine control system to give a tune reading updated at 1Hz.

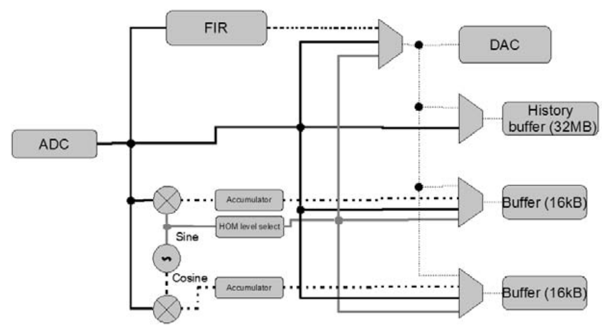

Figure 4: High level logical schematic of the FPGA.

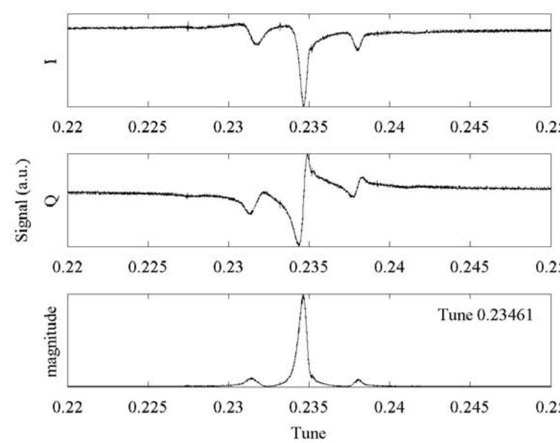

Figure 5: The top two graphs show the I and Q data streams. The bottom graph is the sum of the squares of I and Q and gives the tune line and sidebands.

Additionally we have implemented in the FPGA the recording of the maximum and minimum ADC readings for each bunch. This gives us a proxy for standard deviation, and the difference gives a good measure of the stability of each bunch position. The routine compares the current ADC value of each bunch with stored maximum/minimum values on each turn. If the current value is higher than the maximum (or lower than the minimum) stored value, it replaces that value. The stored value is reset when the data is read allowing us to control the integration time at the user interface level.

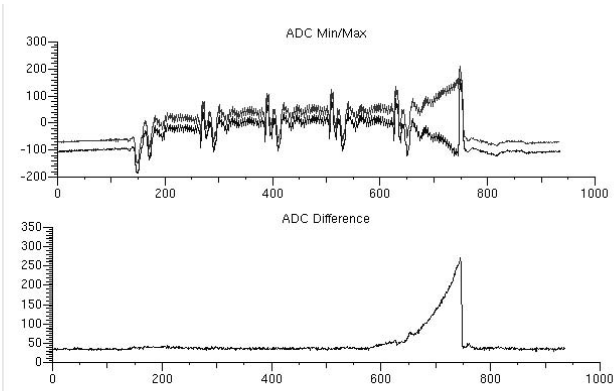

Figure 6: Minimum/maximum ADC readings per bunch from the FPGA. Lower graph shows the difference between the two. In this case the signature of an ion instability is clearly visible.

For any given bunch we can apply feedback, excitation or simply do nothing. Using this we have successfully trialled knocking out a single bunch by switching that position to excitation (figure 7). By closing the collimators this bunch was almost entirely removed (figure 8).

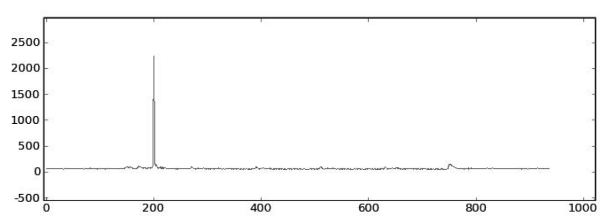

Figure 7: Difference graph showing large transverse motion in one excited bunch in the train.

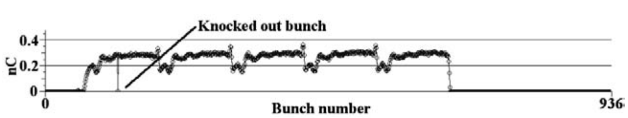

Figure 8: Fill pattern showing the knocked out bunch.

FUTURE DEVELOPMENTS

The ability to excite and remove individual bunches opens the possibility to do bunch cleaning, for example to improve the purity of a single bunch by removing the charge in the neighbouring bunches.

The accumulators can either take the data from all bunches, or from selected bunches in the train. This allows us to monitor a subset of bunches for a longer time period than would otherwise be possible.

In the way described above, the tune measurement mode is incompatible with the feedback mode, as all bunches are excited. By using the ability to excite only a single bunch, combined with the accumulators' ability to selectively record a single bunch, we plan to change the tune measurement to act only on one bunch, allowing feedback to run on all the remaining bunches in the train.

Although not in current use, the system also has the capability to set each bunch gain separately. This is potentially useful in situations where different positions have significantly different bunch charge. For example, in hybrid fill where $\frac{2}{3}$ of the ring is filled with small charge and there is a single high charge bunch in the gap.

The sidebands in the tune spectrum retrieved from the I and Q waveforms should also give information about the chromaticity of the machine. By further developing previous work [4][5], we hope to implement a passive 'continuous' chromaticity measurement.

CONCLUSION

As a feedback system the TMBF has proven itself to be highly capable, able to correct any instability mode within 65 turns. Given that the fastest growth time observed so far is 625 turns, this leaves a lot of margin. It has shown itself to be able to stabilise the beam even with negative chromaticity although further work to establish its limits remains to be done. The max/min outputs allow us to quickly identify the type of instability which is dominant at a particular time, and the continuous tune measurement gives us the ability to track the tune for example during injection, giving us a better understanding of the machine.

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