Measurement Techniques Using the Tektronix® 3052 DSP System

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Abstract

The Tektronix 3052 DSP System contains a 26MHz A/D converter and 1024 parallel digital bandpass filters. It allows a 10MHz wide spectrum to be viewed as a function of time with a maximum update rate of 1 spectrum per 200μs. This paper will illustrate the uses and limits of the device for the Fermilab Booster in applications such as tune measurement and coupled bunch mode diagnostics.

I. INTRODUCTION

This paper discusses the application of the Tektronix 3052 DSP System on the Fermilab Booster. The system provides a solution to many of the problems associated with tune and coupled bunch mode instability measurements of the Booster.

The Booster is a medium energy synchrotron accelerator. It accelerates a 200MeV proton beam to 8GeV where it is injected in to the Main Ring. The RF accelerating voltage must ramp from a frequency of 30MHz to 53MHz in a cycle time of 33ms. The non-linear frequency ramp has a peak slope of 2GHz/s near the beginning of the cycle.

Because of the fast frequency ramp, many of the standard methods for measuring tunes, chromaticities, and instabilities cannot be used on the Booster. A spectrum analyzer cannot sweep fast enough to see the Booster RF cycle, let alone see a change in tune. A digital scope with FFT capability only has enough memory to catch a small time window. It will not show a change in the frequency component as a function of time in the Booster cycle.

Before the 3052 was available, the only way to measure tunes in the Booster quickly was with a custom system[1]. The system is fast, but it is not very flexible once the hardware and programming are completed. The 3052 offers a fast, more flexible system to measure tunes and coupled bunch modes.

II. TEK 3052 FUNDAMENTALS

A. Functional Block Diagram

The functional block diagram of the 3052 is shown in Figure 1 [2]. A 10MHz low pass filter band limits the input signal. The signal enters a variable amplifier and attenuator before being over sampled by a 26.5MHz A/D converter. This digital data is split 1024 ways and enters a digital filter bank. The data from the filters is processed and relayed to the monitor.

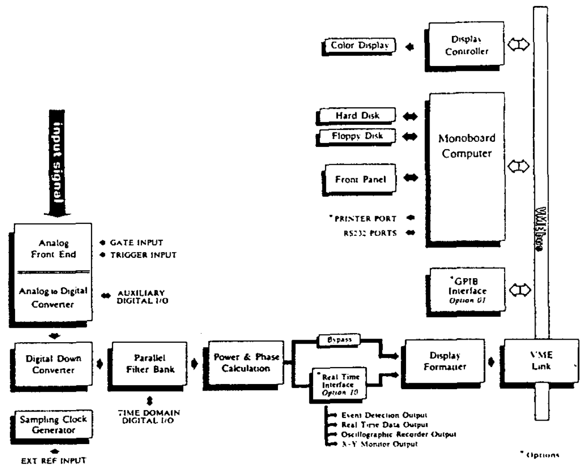

Figure 1. Tektronix 3052 Block Diagram

The data may also be processed by the monoboard computer. This computer operates under a UNIX operating system, and it can store data and C programs in its memory. Thus, a user can customize the data processing for each particular application of the system by calling an application program stored on disk.

B. Specifications

Table 1 shows some of the important specifications associated with the Tek 3052 [3].

III. BOOSTER TUNE MEASUREMENTS

A. Front End

A stripline pickup detects the transverse position of the Booster beam signal, and the difference signal is input in to the Tek 3052. The detector attenuates the first 10 MHz of beam signal because of its frequency response. To increase the signal level, the pickup signal is mixed with the RF signal from the VCO. This allows the 3052 to see the first 10MHz after the first RF harmonic, which has a higher pickup response.

The dynamic range of the input signal is very large. The RF component of the beam signal is more than 60dB greater than the betatron frequency component. An extra 10 MHz bandpass filter was added to the front of the 3052, because its internal filter does not roll off fast enough to keep the RF component from aliasing in to the frequency band.

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B. Triggering

Booster beam is injected, accelerated, and extracted in a period of 33ms, and the video update rate of the 3052 is up to 350ms. Therefore, the data for a Booster cycle must be taken, stored in memory, and displayed at some time after processing is complete. A trigger is required to synchronize the start of data acquisition with the start of the Booster cycle.

The 3052 has three triggering modes for data acquisition: start/stop, single, and continuous. The continuous mode is convenient for data in storage rings [4] because changes happen very slowly. None of these modes are convenient for triggering data acquisition in the Booster because of the quick cycle time and multiple frames. Thus, a custom application program triggers the 3052 to take a block of spectrum measurements for 33ms at the maximum rate of 5 kHz.

Table 1
Span Related Characteristics

Span	Bin Width/ Resolution Passband	Spectral Frame		Spectral Frame Rate / Resolution Passband	Sensitivity @ 1 MHz		
	(0.05 dB Bandwidth)	Interval	Rate		dBm	dBv	dBmV
10 MHz	12.5 kHz	200 µs	5 kHz	0.4	−107	−120	-60
5 MHz	6.25 kHz	200 µs	5 kHz	0.8	−110	−123	-63
2 MHz	2.50 kHz	200 µs	5 kHz	2.0	−114	−127	-67
2 MHz	1.25 kHz	200 µs	5 kHz	4.0	−117	−130	−70
500 kHz	625 Hz	200 µs	5 kHz	8.0	−120	−133	-73
200 kHz	250 Hz	1 ms	1 kHz	4.0	−124	−137	-77
100 kHz	125 Hz	1 ms	1 kHz	8.0	−127	−140	−80
50 kHz	62.5 Hz	1 ms	1 kHz	16.0	−130	−143	−83
20 kHz	25 Hz	5 ms	200 Hz	8.0	−134	−147	-87
10 kHz	12.5 Hz	5 ms	200 Hz	16.0	−137	−150	−90
5 kHz	6.25 Hz	5 ms	200 Hz	32.0	−140	−153	−93
2 kHz	2.5 Hz	25 ms	40 Hz	16.0	−144	−157	-97
1 kHz	1.25 Hz	25 ms	40 Hz	32.0	−147	−160	−100

Maximum Dynamic Range without Distortion = 58dB
Total Dynamic Range with Front End = 183dB

C. Processing

Once the block of data is stored in memory, the data may be processed in any format the user desires. A C program processes the raw data from the tune measurements by shifting the frequency of each frame. The program uses a set function to determine the frequency shift as a function of time in the Booster cycle. An example of vertical tune measurement and processing is shown in Figure 3.

IV. COUPLED BUNCH MODE MEASUREMENTS

Another application of the Tek 3052 is the measurement of the amplitude and growth rate of coupled bunch modes. The 3052 spectrogram/spectrum analyzer mode measures the coupled bunch modes in the Booster using the same triggering scheme developed for tune measurements. In this display mode, the spectrum analyzer plot represents one frame of the spectrogram, and the frame displayed is set by the spectrogram marker. By adjusting the time coordinate of the

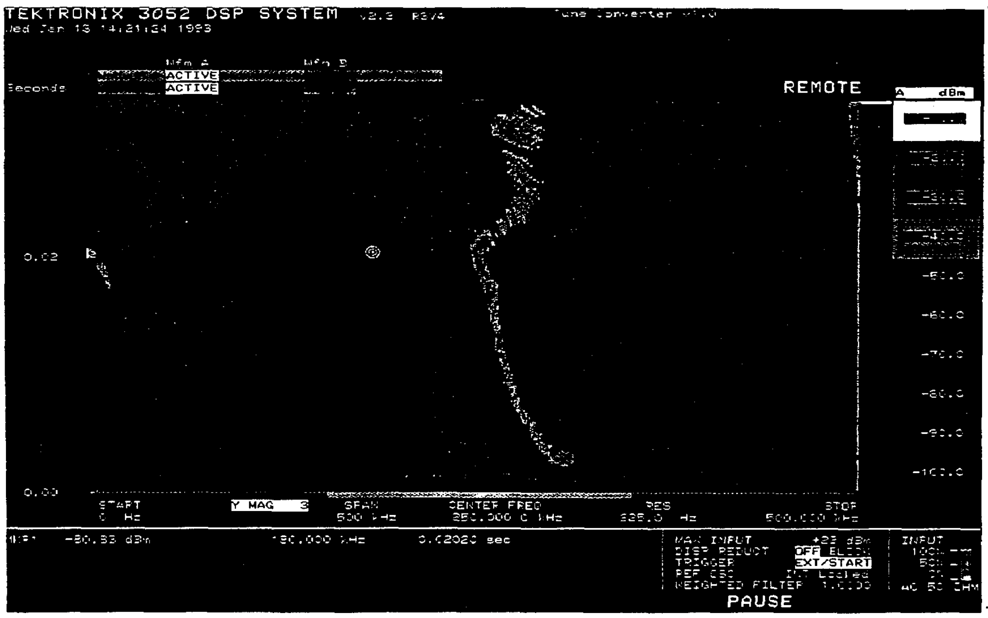

Figure 3. Processed vertical tune measurement in spectrogram display mode.

spectrogram marker, the change in coupled bunch mode amplitude can be seen on the spectrum analyzer plot.

A more convenient way to view the growth of the coupled bunch mode is to look at a collection of spectrum analyzer plots. The 3052 has a waterfall display mode illustrated in Figure 4 which gives a three dimensional plot of time, amplitude, and frequency. This format gives a better indication of the growth rate of the coupled bunch mode.

Unfortunately, because of the 10MHz bandwidth limit of the 3052, less than half of the possible modes are displayed.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

[1] G. Wu et al., "A Pseudo Real Time Tune Meter for the Fermilab Booster," *Proceedings of the 1991 AIP Accelerator Instrumentation Workshop*, pp. 276-284.

[2] Tektronix Federal Systems, Inc., "3052 Digital Signal Processing System," 4.

[3] Ibid., 5

[4] K.J. Cassidy et al., "Development of a Model for Ramping in a Storage Ring," *Proceedings of the 1991 AIP Accelerator Instrumentation Workshop*, pp. 148-149.

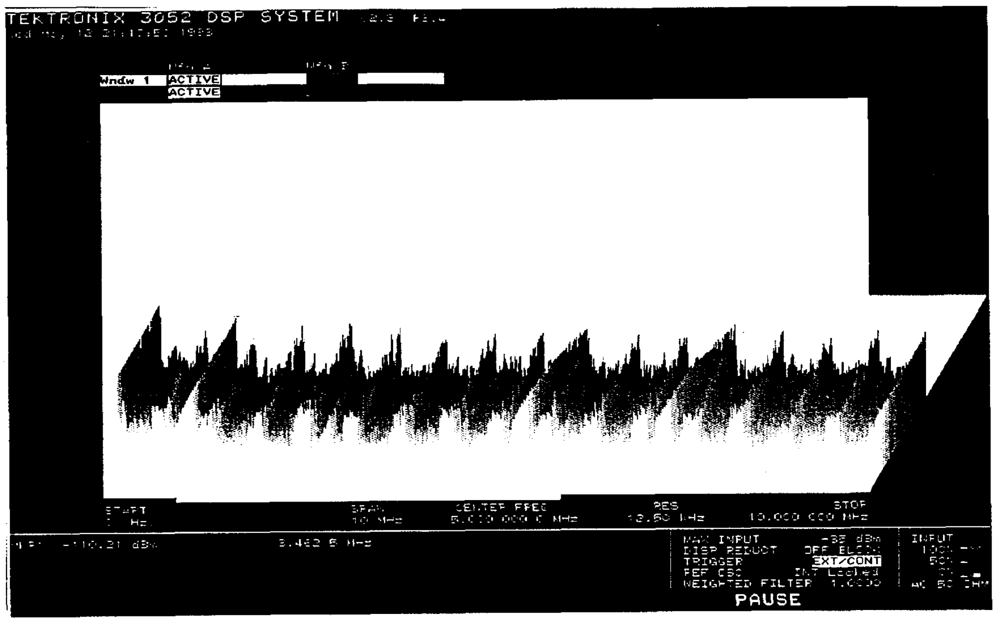

Figure 4. Waterfall display of transverse coupled bunch modes