Elettra BPM system (Hardware and Software); first results.

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Abstract

The Elettra BPM system is a combination of high performance hardware and high performance low level software called 'DET'. The main tasks of 'DET' software is: control of eight BPM detector's including hardware functionality tests; position' calculation including the normalisation factors from mechanical and electrical calibrations; gain control of the detectors; special math functions, like averaging and rms. deviations; communication with the ELETTRA control system. The purpose of this software is to have an 'intelligent' system at low level to reduce the communication traffic and increase the entire system reliability with minimum load on the control system. Three different modes of operation are available to the system: First Turn Mode, Closed Orbit Mode, Harmonic Feedback Mode [1]. The first results of BPM system operation are reported. The global accuracy and long term stability have shown to be well within specifications. Both first turn and closed orbit modes have been used successfully.

1 INTRODUCTION

A Beam Position Monitor System has been developed and successfully installed at Elettra. The system was immediately integrated in the Elettra Control System and all the position data were available for an Orbit Correction [2]. Other high level applications [3] have used this data for beam optimisation in both First Turn Mode and Closed orbit Mode. This was possible because of the complete software handling of the hardware which gives obtain the maximum flexibility to the system.

The electronic part of the system is composed by twelve EIUs (Equipment Interface Units), each of which controls eight BPMs [4]. The EIU is composed by a VXI Crate equipped with one Eltec's CPU (Eurocom 6: 68030 CPU @25MHz, 68881 FPU) and by a MIL1553 standard communication board. The other boards, developed in house, are: an Auxiliary board (with a 510Mhz Local oscillator & timing interface), a general purpose RF Multiplexer board and four BPM detector boards, each of which contains two BPM detectors.

2 HARDWARE

The detector electronic is composed by tree parts: the RF/input (fig.1) the IF/AGC/Integrator (fig. 2) and the Timing/ADC/DAC/bus (fig. 3). The latter part is common to two BPM channels.

2.1BPM detector RF /input

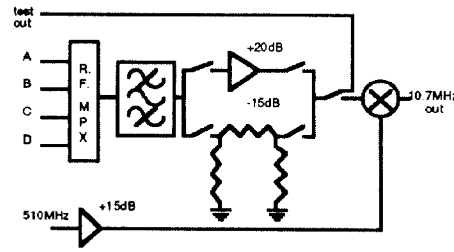

Fig. 1 BPM detector RF part

The RF/input handling software directly controls the amplifier/attenuator/test_exit switches. The multiplexer selection inputs are hardware generated by the timing of the board. The RF input part is critical for the absolute accuracy of the beam position calculation. Therefore, the input stage and the annexed cables from the electrodes, have been calibrated on field to compensate the little differences among the four channels and to minimise eventual impedance mismatches A first calibration with the amplifier active, was performed by injecting a 499.654MHz signal at the end of each cable using a generator with the same BPM button impedance [5]. To obtain the calibration factors with attenuator active a real beam was used. The difference between the two coefficients was generally very little, but in some cases before the calibration, there was a step of 100µm. This effect is due to a little difference in the input impedance of the attenuator respect to the amplifier (approx. 2%).

2.2 BPM detector IF/AGC/Integrator part

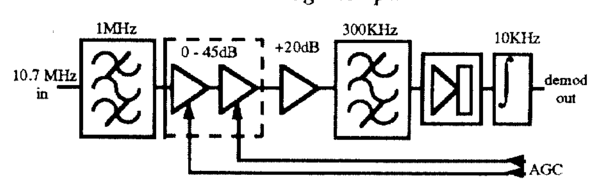

Fig. 2 The IF/AGC/Integrator

The IF/AGC/Integrator requires a software regulation of the AGC voltages to maintain the highest electrode value at 90% of the ADC converter, corresponding to the linear region of AM detector. The software is also responsible for the AM detector calibration factor, which compensates the real zero level.

The integrator cut-off frequency is set by the software to be 1KHz or 10Khz according to the selected operating mode.

2.3 BPM detector Timing/ADC/DAC/bus.

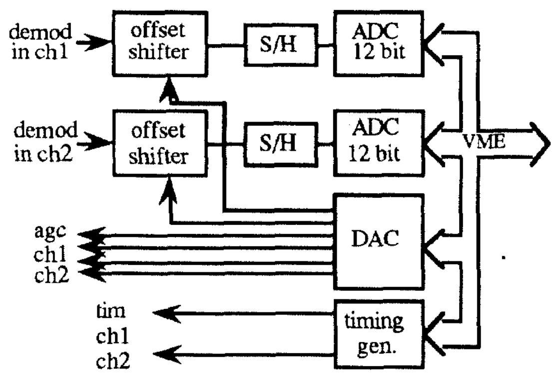

Fig. 3 Timing/ADC/DAC/bus

This part requires several software controls, like real time reading of the ADC values. Polling mode was found to be the only solution since the rate is too high (particularly in feedback mode) for a hardware interrupt (20 KHz per detector). The other required functions are: the selection of the timing rate, setting the DAC for hardware-compensated AM detector 'zero offset' value and setting the DAC for the Auto Gain Controls.

3. SOFTWARE

3.1 Initialisation

The low level software is identical for all EIUs. At start-up, it recognises its EIU and the serial code number stored in PROM for each Detector board. Furthermore, it reads two configuration files: one to decode the 'point' in the control system (S1.1 to S12.8) and one with the calibration factors. This database is very useful to check system connections and to avoid mismatches in calibration factors or in decoding point. The software also perform a hardware check on the BPM detectors (routine performed also during normal operation), and retrieves from the Non Volatile Ram some parameters such as previous detector mode and averaging factor). The latter give the possibility to reset or to power off one EIU without losing the previous status

3.2 Acquisitions

After initialisation is done, the system starts the continuous beam position acquisition, according to the selected mode of operation which may be: First Turn (with a 10 Hz sampling rate), Closed Orbit (1KHz) and Feedback(20 KHz). The system uses the same electronics for all the modes. However the software changes some hardware parameters, such as the timing and the integrator filter response, and some software parameters, like AGC algorithm. The software acquires continuously the position and places all the data into a circular buffer. The data are immediately ready for high level requests, and an averaged value is returned. The average is a user defined parameter and may be set from 1 and 1000.

The biggest difference in the acquiring process is between the First Turn Mode and the Closed Orbit Mode. In the First Turn Mode, the beam is present in the ring it's present only as a burst of bunches injected by the Linac at 10Hz and with a current between 0.2 and 2 mA. Since the BPM Detectors cannot process the signal in less than 50µsec, four bursts, one per electrode, are used to calculate one position. The limits of this measurement are two: the time to determine a position (2.5 positions per second) and the dependence of the calculated position on the stability of the injection. To obviate the beam position dependence on injection conditions, an averaging of 30 beam positions was performed, increasing however the time for determining the position.

3.3 Averaging

The EIU have an averaging algorithm. Any reading instability may decrease increasing the number of averages until a good reading stability is obtained. The averaging algorithm allows also the calculation of the rms. deviation of the readings. All of these data are returned together with the positions. The readings' rms. deviation of the position is useful to find the best averaging number. The lower limit is found when the rms. deviation is lower than the reading stability. The averaging algorithm is used also in Closed Orbit Mode to bypass any reading fluctuations. All frequencies less than 1KHz influence the stability reading. The averaging number normally used in Closed Orbit Mode is 500, and the values are averaged for 2.5 seconds: this allows to bypass low frequency oscillations up to4Hz.

3.4 Calculations , calibrations and offsets

The formula used to calculate the horizontal X and vertical Y absolute positions, relative to the magnetic centre of the quadrupole at which the BPM is fixed, are:

$$X = X_{factor}\frac{(Va + Vd) - (Vb + Vc)}{Va + Vb + Vc + Vd} - X_{offs}$$

$$Y = Y_{factor}\frac{(Va + Vb) - (Vc + Vd)}{Va + Vb + Vc + Vd} - Y_{offs}$$

Where: Xfactor (19.69) and Yfactor (19.46) are the geometric coefficients of the BPM, Va, Vb, Vc and Vd are the voltages on the corresponding electrodes scaled with the appropriate calibration coefficients (see 2.1), and Xoffs, Yoffs are the mechanical offset between magnetic quadrupole centre (where the BPM is fixed) and mechanical centre of the BPM and the offset between the mechanical and electrical centre of the BPM.

3.5 Automatic Gain Control

The AM detector has a good linearity (<0.1%) in the 10 dB range: for this reason the AGC routine maintains the level of the larger electrode signal at 90% of the range. In this way the best noise ratio from the ADC converter is obtained. In fact the range of the ADC is 4096 (12bit), with a noise of 0.5 (1/2bit). The algorithm used is 'successive approximation' with three programmable parameters: a Target value (default 3600, 90% of range), a Window Around Target (default 50, ±25) and an Average Value (default 30). The algorithm is very simple and not very efficient in speed, but it was chosen because there are two non-linear AGC voltages and the prediction would have been more complicated and slower. The time response of AGC is less than five seconds. The dynamic range in the design was 1-400mA; the effective range for all 96 BPM detectors is 0,2mA-540mA, and 60mA in Single Bunch.

4. MEASURES

4.1 System specifications requested:

Resolution : ≤ 5 μm (at high currents)
Stability eight hours : ≤ 10 μm rms.
Absolute accuracy : ≤ 150 μm rms.
First turn mode acquisition speed : >1 trajectory/min
Closed orbit mode acquisition speed : >2 graphics/second
Position feedback acquisition speed : ≥ 2800 orbit/second
Dynamic range : 1mA - 400mA

4.2 System specifications obtained:

Resolution measured: 2.5 μm (1-550mA)
Stability eight hours : not yet directly measured
Stability: see fig 4, fig. 5.
Absolute accuracy measured: not directly measured; dispersion measurements confirmed a closed orbit with 150 μm rms. in both planes(see also fig. 6)
First turn mode acquisition speed obtained: continuous reading, 12 seconds for new orbit before any variation
Closed Orbit Mode acquisition speed obtained: > 5 graphics per second (depend from traffic on the control system)
Position Feedback acquisition speed obtained: 4000 orbit per second (this value is the limit of the BPM electronics hardware and software; the position feedback isn't yet active)
Dynamic range measured: 200μA - 540mA

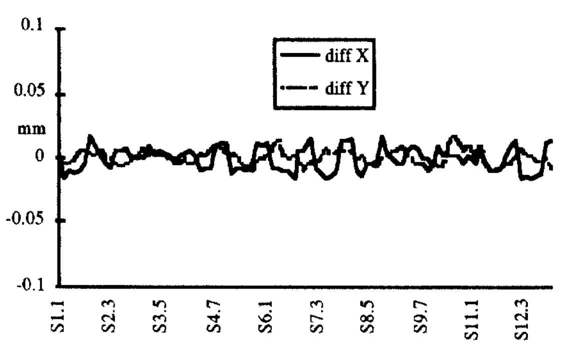

Fig 4 Difference between 10mA and 200mA orbit

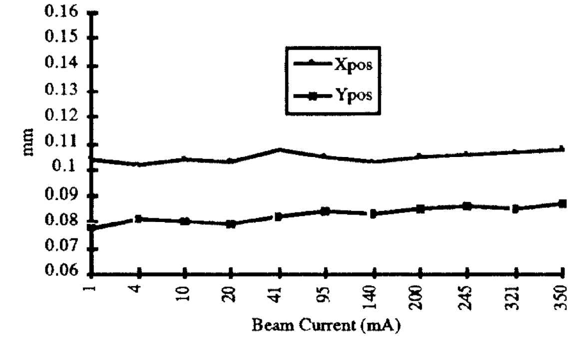

Fig 5 BPM position versus beam current

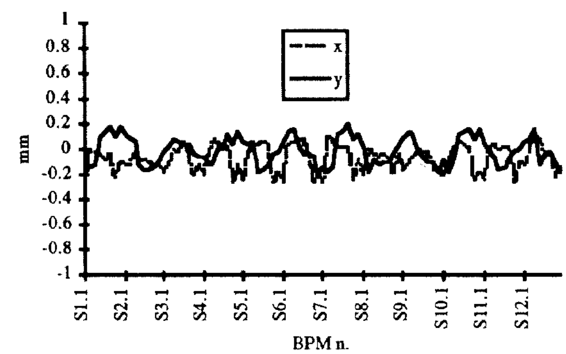

Fig 6 Corrected orbit @ 10mA

5 EXTRA FEATURES

The BPM system is also able to digitise the input signals at 1KHz and at 20Khz and store the data in a file. It's possible to use this data to calculate a power spectrum of any instabilities.

6. REFERENCE

[1] D. Bulfone et al. "Position Feedback System for ELETTRA", Proceedings of the EPAC 92 Nice.
[2] R. Nagaoka, "Orbit Correction in ELETTRA", this conference.
[3] M.Plesko, "The High Level Software of ELETTRA", this conference.
[4] J.C. Denard et al., "Beam position monitoring system for ELETTRA", proceedings of the EPAC 92 Nice.
[5] R.Ursic et al, "High Stability Beam Position Monitoring of ELETTRA", Presented to First European Beam Instrumentation Workshop, Montreux.