500 MHz Narrowband Beam Position Monitor Electronics for Electron Synchrotrons

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Abstract. Narrowband beam position monitor electronics were developed in the Forschungszentrum Jülich-IKP for the orbit measurement equipment used at ELSA Bonn. The equipment uses 32 monitor chambers, each with four capacitive button electrodes. The monitor electronics, consisting of an rf signal processing module (BPM-RF) and a data acquisition and control module (BPM-DAQ), sequentially process and measure the monitor signals and deliver calculated horizontal and vertical beam position data via a serial network.

INTRODUCTION

The beam position monitor system at ELSA Bonn (1) consists of 32 monitor chambers, each having four capacitive button electrodes. For position measurements, the narrowband signal chain tuned to the fundamental harmonic of the bunch frequency is used. The position data are proportional to the quotient of the difference and sum signals and to a coefficient depending on the monitor geometry (K_x, K_y). The electronics described in this paper uses the sequential processing method (2,3). In each acquisition cycle the button signals (V_{LU},V_{RU},V_{LD},V_{RD}) are measured first, then the position data are computed as follows:

$$P_X = K_X * \frac{(V_{RU} + V_{RD} - V_{LU} - V_{LD})}{(V_{LU} + V_{RU} + V_{LD} + V_{RD})} \tag{1}$$

$$P_Y = K_Y * \frac{(V_{LU} + V_{RU} - V_{LD} - V_{RD})}{(V_{LU} + V_{RU} + V_{LD} + V_{RD})} \ . \tag{2}$$

MEASUREMENT ELECTRONICS

The rf section (Fig.1), consisting of narrowband superheterodyne rf electronics, processes the fundamental bunch frequency (number of bunches along the accelerator ring, multiplied with the revolution frequency) component of the button signals. At the input, low-pass filters reject the higher harmonics, and a GaAs analog rf multiplexer scans sequentially the output of the filters. A low-noise narrowband preamplifier (*B*=5MHz) amplifies the selected low-level button-signal. For very high signal levels, a 30dB attenuator can be inserted. A GaAs mixer transposes the desired frequency range to the intermediate frequency, where narrowband filters reduce the if bandwidth to 220kHz and if amplifier with controlled gain enhances the signal level appropriately for demodulation.

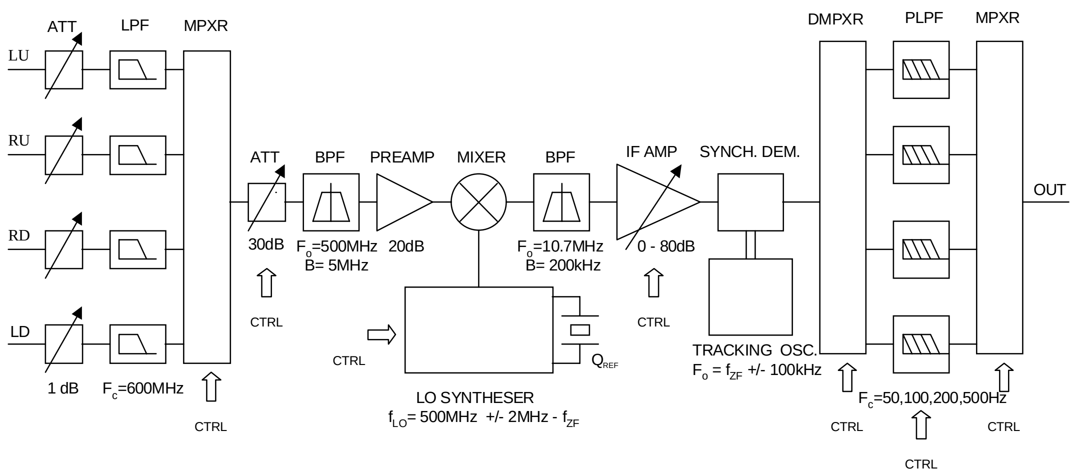

FIGURE 1. Block diagram of the rf signal processing module.

An on-board synthesizer generates the LO signal applied to the mixer. Its frequency determines the band-center frequency of the signal processing. Due to the low particle mass the revolution frequency is nearly constant in the acceleration ramp. Small frequency changes during the ramp within the if bandwidth will be automatically tracked by the demodulator in real time. Band-center frequency adjustments for special measurement purposes can be achieved by synthesizer remote control in the range of 500 MHz ± 2 MHz with 50 kHz steps.

The output signal of the highly linear synchronous demodulator is proportional to the rms value of the fundamental component of the amplified button signal and carries amplitude changes with frequencies up to 500 Hz. The overall demodulation bandwidth can be selected by means of switched filters to frequencies between 0.1 Hz and 500 Hz in 13 steps. The gain control range of the processing chain is about 100 dB. Signal levels between –80 dBm and +10 dBm are allowed. Scan timing and the step gain control are synchronized; four button signals will be measured in each cycle with the same gain, so consistent data can be used for position computing. The scan sequence of the button measurements is programmable.

The data acquisition module (Fig. 2) consists of an 8-bit microcontroller with an 8 kbyte EPROM and 32 kbyte RAM and built-in timer, a half-duplex 1 Mbit/s asynchronous serial interface, with a galvanic isolated twisted-pair transceiver for data communication, a 12-bit ADC for digitizing of the demodulated electrode signals, a 12-bit DAC for gain control, several bits for timing and bandwidth control, and a 3-wire serial interface for synthesizer control.

The timer of the microcontroller controls the rf multiplexer and the timing phases of the acquisition. After digitizing of the button signals, depending on the acquisition parameters, the microcontroller filters by means of a digital lowpass filter (0.1–500 Hz) and/or averages the signal values for the preset number (1–4096) of measurement cycles. Although the acquisition frequency is always 1 kHz, the transfer rate can be set by remote command to 1–256 ms, corresponding to the selected lowpass filter. Data transfer begins after the averaging is finished.

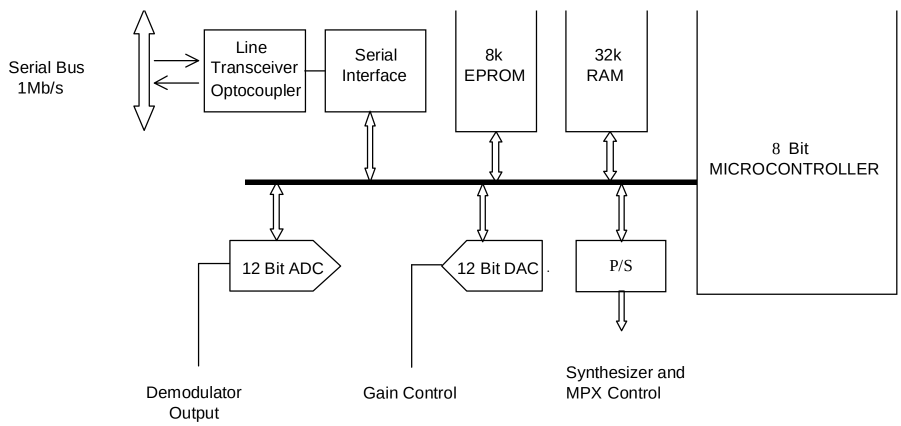

FIGURE 2. Block diagram of the data acquisition and control module.

DATA COMMUNICATION

A control module and an rf module form a BPM station. A group of eight stations is connected to the host computer via a serial bus with 100 m maximum length. The whole installation consists of four such groups, each with eight stations. The host initiates the data transfer; data collision is not allowed.

CONCLUSIONS

Compared to the parallel acquisition method (producing a sum and difference signal and processing them simultaneously with separate electronics), the sequential method measures the monitor signals with the same electronics. The time resolution of the monitor electronics described here is 1 ms; the position resolution is 0.5µm (@ B_{res}= 1 Hz, P_{in}= –40 dBm, K_{BPM}=14.5 mm). Advantages of the sequential data acquisition include:

- the minimization of differential measurement errors by using a single signal processing chain; and
- cheaper measurement hardware due to the single signal processing chain.

Possible disadvantages include:

- a 25% signal-processing speed, compared with a parallel signal chain system having the same rf bandwidth; and
- pseudo beam position changes at rapidly changing signal levels (filling/fast extraction), due to the time delay between the four measurements within one cycle.

Proper additional circuits and algorithms prevent the theoretical disadvantages, and so sequential acquisition has proven to be the more accurate and cheaper solution in beam position electronics.

REFERENCES

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