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CONSTANT MAGNETIC FIELD MEASURING SYSTEM IN THE U-70 SYNCHROTRON

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Abstract

The mode of operation of the synchrotron for the circulation and retardation of carbon ions, using an independent programmable power supply of the ring electromagnet, required the creation of a system for measuring the constant magnetic field. This special power supply program forms the synchrotron “Magnet Cycle”. It has the main plane part for beam injection and circulation and the medium plane for beam ejection stage. The medium plane magnetic field value defines the beam output energy. The measured values of the magnetic field on both the main and the medium plates of the cycle provide information important for the synchrotron operation.

MEASURING SYSTEM

The measuring system includes: magnetic field permalloy probe, the head electronic module, RS – 485 Interface, CPU, main U – 70 Control System.

The permalloy probe [1] is a specially designed permalloy wire core placed into a small diameter glass tube with two outer coils – signal coil and current one. The probe is placed on a moving plate, connected to a mechanical actuator and located in the measuring electromagnet pharynx (see Fig. 1). The measuring electromagnet is connected in parallel with the ring electromagnet. When the magnetic field vertical component (across the core axis) crosses the zero value, the signal coil generates a short pulse (see Fig. 2).

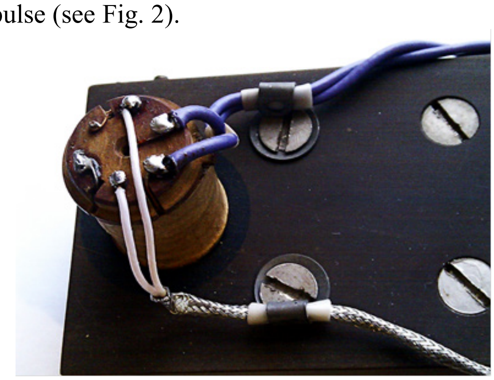

Figure 1: Permalloy Probe on the Actuator Plate.

The Block diagram of the measuring setup is shown in Fig. 3. The “StartIn” pulse from synchronization system comes to the digital measuring part to generate the strobe pulse (12 ms) to start the electron integrator. The ramp function current flows to the current coil of the probe (0 – 2A range maximum) after the integrator output signal amplification (PWR AMP). When the current coil magnetic field value becomes equal to the measured electromagnetic field, a pulse appears on the signal coil. Calculating the quantity of periods of the known frequency (20 MHz@50 ns) from “StartIn” to “MeasIn” pulses, one can obtain a value proportional to electromagnetic field.

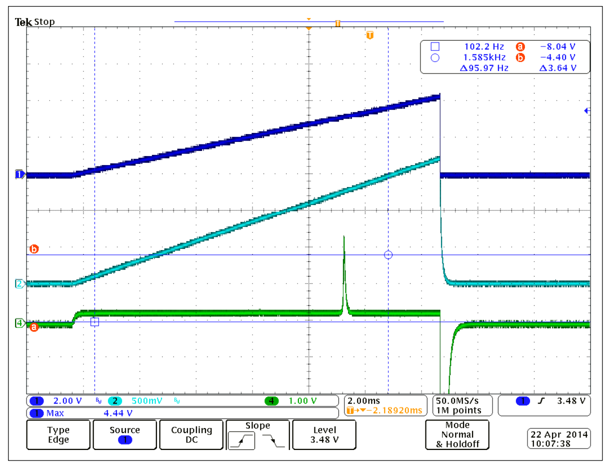

Figure 2: Measuring the Pulse from the Probe Signal Coil (4-th trace).

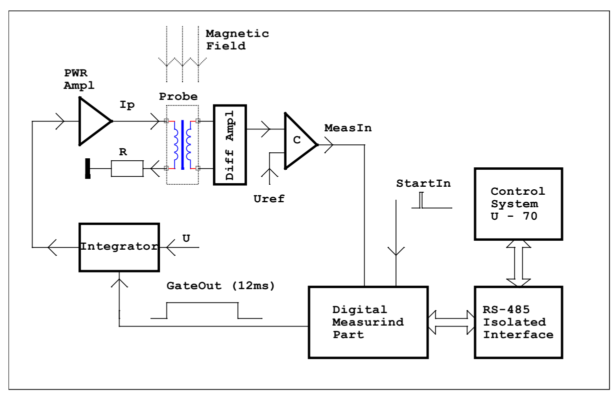

Figure 3: Measuring Setup Block Diagram.

To carry out accurate measurements, it is necessary to detect the midpoint of the “MeasIn” pulse. This is the main difficulty in making measurements, because its shape depends on the derivative of the magnetic field (for different values of the different pulse widths). In addition, at the beginning of the current build-up in the coil, a series of false impulses appear at the sensor output, which it is necessary to dispose of. This difficulty can easily be overcome with the proposed algorithm of digital signal processing. Its essence is shown in Fig. 4.

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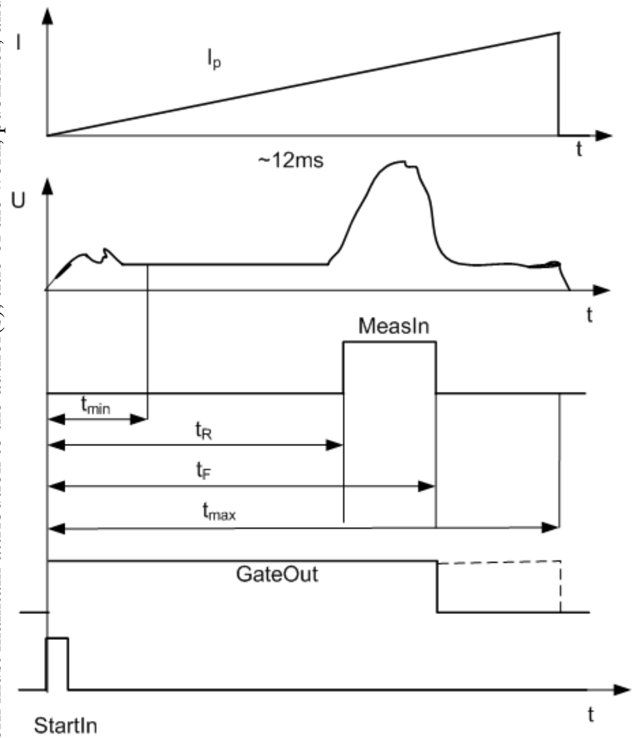

Figure 4: Measuring Setup Block Diagram.

The digital part of the algorithm is implemented in the programmable CPLD chip Altera EPM7064SLC44-10. When the start pulse of the “StartIn” measurement starts from the U-70 synchronization system, a “GateOut” enable pulse is formed, along which a linearly increasing current is applied to the coil. The counter of the 20 MHz series is launched and a measurement flag is read by the microcontroller. The comparator input receives a signal from the sensor. During the first ~ 2 ms (time t_{min}), the pulses generated by the comparator are ignored. At the end of this "dead zone", the signal is considered working and is subject to processing. At the arrival of the leading and trailing edge of the “MeasIn” pulse, the counter values (CR CF) are stored and then the pulse center is in terms of the number of pulses $C_M = (C_R + C_F) / 2$. Upon arrival of the trailing edge, the current is cut off. If the trailing edge is not fixed for a time t_{max} ~ 12 ms, the current source is disconnected. The measurement cycle is considered complete, as indicated by the status signal. Having received the measurement signal through the interrupt, the microcontroller reads the value of C_M and transmits the data to the electronics room. The distance from microcontroller to the electronics room is 800 m. For data transmission, an opto-isolated RS485 interface with 4800 baud speed is used. The data is transformed into TTL level and received by the microprocessor module Tam3517. In this module the measurement cycle is formed and the primary data processing is performed. Then the data enters the control system of the accelerator complex. When the data is written by the control system, a number of C_M pulses is converted into gausses using a linear transformation. The calibration factor is obtained experimentally, by measuring the closed orbit of the beam and the values of the frequency of the accelerating field. The obtained measurement data are in good agreement with the calculated data. An approximate view of the control system screen is shown in Fig. 5.

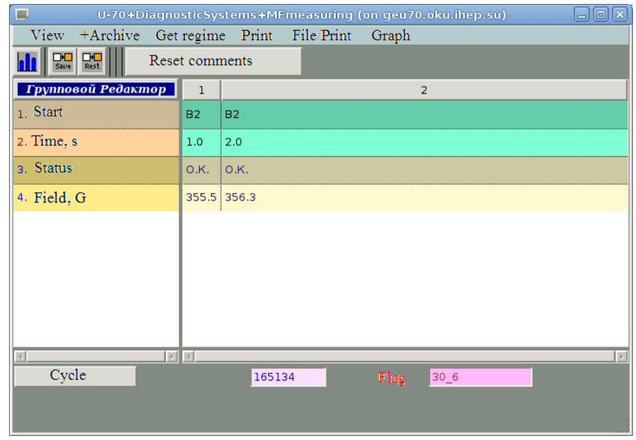

Figure 5: Control System Screen View.

CONCLUSION

The constant measuring system was created and implemented for U – 70 Synchrotron. The system was successfully tested with the beam during the machine run. Achieved system parameters:

- Measurement range: 100 – 440 G
- The achieved measurement accuracy: is 0.05 G
- Number of measurements in one cycle of the accelerator – 2. It is possible to carry out the both measurements from two different pulses of the accelerator synchronization system.

REFERENCES

[1] B. Kalinin et al, Manufacturing and Implementation of magnet saturated permalloy probes, TPU Reports, Tomsk, 1969, vol. 156.