THE NEW VME-BASED SYSTEM FOR MAGNETIC MEASUREMENTS WITH HALL SENSORS

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Abstract

Systems with Hall sensors are widely used for magnetic measurements. The paper describes the new VME-based system and MS Windows application developed for replacement of the old system at BINP measuring stands. Features of specialized VME-units and new software capabilities are reported. Examples of application and practice results are also presented.

INTRODUCTION

CAMAC – electronics was used for creation of measuring systems with Hall sensors in BINP for many years [1]. These systems had good parameters and were successfully used for measurements of magnets produced in BINP as for installations of VEPP-family as for out-of-BINP facilities: Siberia-1, -2 (KSRS, Russia), LHC (CERN), SLS (Switzerland), BESSY (Germany), SAGA (Japan). Hardware deterioration and MS DOS application of previous system demanded to design a new electronics and modern software.

Hall measuring system can be assembled on the base of multi-purpose instrumentation, like precision voltmeters, analogue multiplexers, current sources etc. Unfortunately, the similar way of building Hall measuring system appears redundant and expensive enough, but not always meets all requirements to such systems.

Note also, that for controlling the peripheral equipment like power supplies or stepping motors, the system should contain corresponding interface devices. The modular system, including a specialized and interface modules, looks quite suitable to solve problem.

Thus, we decided to design specialized, easy-to-replicate, BINP-made, VME-based Hall measuring system. Now this work is close to end.

ELECTRONICS OF HALL-SENSOR MEASURING SYSTEM

The Figure 1 demonstrates the structure of measuring system.

The last one consists of several modules, installed at VME-crate: controller BIVME-1, VME↔RS-232 interface, VME↔CAN interface and three specialized units: Hall Sensor analogue Interface (VMEHSI), precision ADC (VMEADC16) and Hall Sensor Thermo Stabilizer (VMEHTS). All modules, except RS-232 interface, are fabricated in Budker INP. During calibrating procedures the set of specialized NMR units [3] may be installed in crate. For this case the total space is 11 units.

External devices are: carriage with sensors, step motor controller, located close to step motor at carriage moving assembly and magnet power supply.

RS-232 interface controls step motor controller via serial link. Magnet power supply is controlled via CAN-bus with the help of VME↔CAN interface unit.

Hall Sensor analogue Interface VMEHSI is intended for supplying of Hall sensors and for the interfacing of the sensors chain and ADC. Precision ADC VMEADC16 converts output voltages of VMEHSI to 23-bit digital data. Module VMEHTS performs temperature stabilization of holder with Hall sensors. BIVME-1 carries out CPU and VME-master functions.

Essential details and short specifications of electronic modules are presented below.

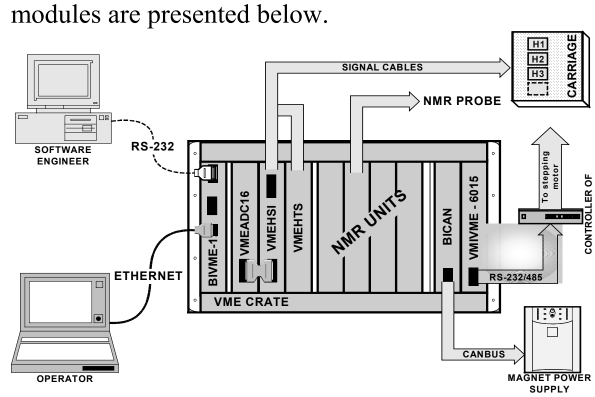

Figure 1: The structure of Hall measuring system.

Carriage and its Thermostabilization

To eliminate thermal dependence of Hall-sensors we decided to stabilize its temperature. Special sensors holder, equipped with heater and thermo probe is developed in order to realize temperature stabilization. The holder is a copper bar on which sensors are mounted. Holder is fixed on a carriage.

VME Hall Thermostabilizer (VMEHTS) module stabilizes temperature of the holder (~40°) with accuracy ±1°C, using linear scheme.

The Hall-Sensor Analogue Interface VMEHSI

VME Hall Sensor Interface was designed as a specialized analog module destined for Hall measuring systems. That circumstance has influenced scheme solution and choice of electronic components.

The simplified structure of VMEHSI is presented at right side in Fig. 2. The main parts of this unit are: 32-channel 3-wire analogue multiplexer, sensor supplying current source and built-in precision output amplifier.

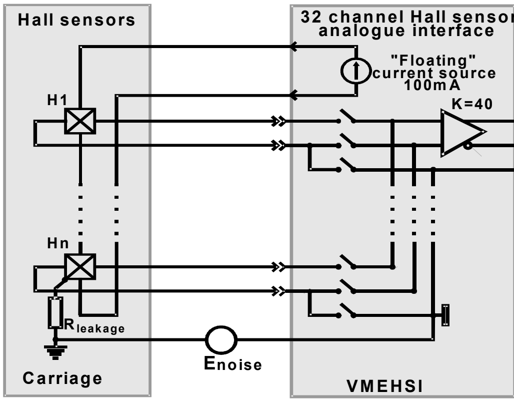

Figure 2: The structure of VMEHSI and its connections to Hall sensor carriage.

This unit determines accuracy of the whole system. Typical Hall-sensor sensitivity is 10 – 20 μV/Gs, so in order to achieve desired error in magnetic field measurement about ±0.1 Gs we need to obtain an error at electronic equipment less than ±1μV.

Five main scheme and design solutions proposed to reach this value. The first – using the semiconductor chip cases with copper pins only in small-signal part. The second – installation the thermo-smoothing pad on printed board. The third – galvanically isolated ("floating") current source for sensor supplying.

Table 1: VMEHSI specifications

Number of input channels	32 differential
Input voltage range	±250 mV
Output amplifier gain	40.000 ÷ 40.002
Gain error	±10ppm
Gain drift	±1ppm/C°
Peak-peak input noise	2μV
Offset drift	±30nV/C°
Hall sensors supplying current	99.996±0.001mA
Current drift	±2ppm/C°
Size	2M

The fourth proposal - three-switches scheme (see Fig.2), which performs "dynamic" grounding of one sensor terminals and in addition eliminates $R_{leakage}$ +E_{noise} influence. The final point of VMEHSI design is built-in precision output amplifier with gain 40.

In standard interconnection of Hall system first six channels of VMEHSI intended for measuring of technological signals. They are: short circuit, Hall supplying current, holder temperature and voltage on sensor's chain. Total amount of Hall probes, which may be used in system, is 26.

Main specifications of VMEHSI are listed in Table 1.

Precision ADC

VMEADC16 based on delta-sigma ADC-chip with differential inputs. An analogue part of device is galvanically isolated.

An on-board micro controller performs the calibration procedure in hidden-of-user way. Microcontroller also manages all of device operations.

The specifications of VMEADC16 are listed below in Table 2.

Table 2. VMEADC16 specifications

Resolution	23bits
Input voltage range	±10V
Accuracy @ 20°÷ 50°	0.003%
Offset	±20μV
Peak-to peak noise @ 20ms	40μV
Effective number of bits @ 20ms	20 bits
Min. Time per measure for Hall system	80 ms

SOFTWARE

The software of the new magnetic measurement system is a complex of functional specific programs. The architecture of the software is based on client-server model (Fig. 3).

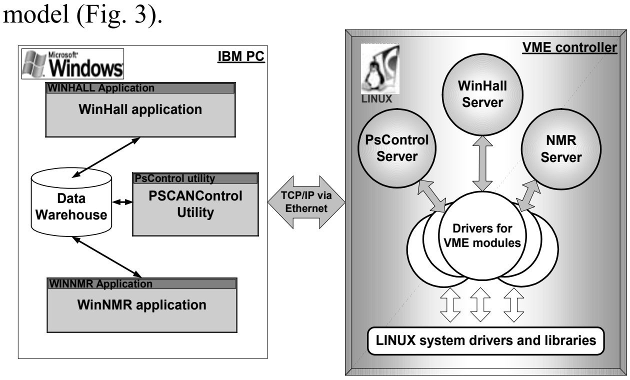

Figure 3: Software architecture of Hall system.

The embedded low-level (hardware specific) software operates on VME-controller under the μcLinux operational system. There are drivers and low-level libraries for all VME-modules. The classical TCP/IP server is started at the VME-controller. The server is responsible for interfacing with clients (high-level task specific software). The embedded software is located on the flash disk as firmware of the system controller and starts-up immediately after power on.

Below are listed client's programs executed in operator's computer under Microsoft Windows 2000/XP operational system:

- **WinHall**. The tasks of main program WinHall are read out of Hall-probes and technological channels signals and processing of these data.
- **PSCANControl**. The task of this utility is a control of magnet power supplies.
- **WinNMR** - the special software for calibration of Hall-probes with the help of NMR-based magnetometer.

The WinHall program is a WIN32 application with user-friendly graphical interface. This program creates the connections to the TCP/IP-servers in the VME system controller and uses it to control the measuring system hardware. The main functions of the WinHall program are:

- Design of experiments. In the beginning of measurements operator setups the list of magnetic elements and list of measurements for each element.
- Planning the moving scenario of carriage, setting configuration of the hardware, measure Hall probes offsets.
- Data storing with the help of date warehouse facilities. “On-the-fly” visualization measured magnetic field.
- Calculation and plotting the first and second integral in real-time.
- Taking into account the influence of perpendicular magnetic field for each Hall-probe.
- “Off-line” visualization and processing of stored data.

The PSCANControl utility is developed for controlling and monitoring the power supplies via CANBus. The program creates the connection with special TCP/IP-server at the VME-controller and uses it to communicate with the power supplies.

An accuracy calibration of the Hall-probes is a crucial factor for good results of the magnetic measurement. The special program WinNMR was developed for calibration purpose. This program is WIN32 application under Windows 2000/XP operational system. To make a calibration file for carriage with the Hall-probes the programs performs all necessary procedures.

EXAMPLES OF APPLICATION

The most interesting works performed with the help of new system were magnetic measurements of undulator HU256 and Permanent Magnet Wiggler [2].

Three elliptical undulators HU256 of electromagnetic type were produced, tested and magnetically measured by BINP for Synchrotron SOLEIL (France).

Magnetic measurements of undulators were provided by 2 methods: Hall probes and stretched wire. For HU256 measurements two identical Hall probe systems were manufactured: one used for magnetic measurement at the Budker INP, other works at Synchrotron SOLEIL. View of undulator and Hall measuring assembly is shown in Fig. 4.

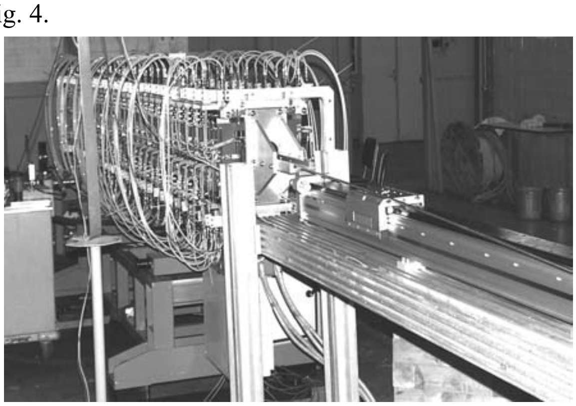

Figure 4: View of undulator and measuring assembly.

The carriage contains two sets of probes located at two thermostabilized holders: first set - to measure vertical field, second one – for horizontal field. To measure field map the carriage is moved along the undulator axis within the aperture with step 4mm. The accuracy of the magnetic field measurement by the Hall probe system is ± 20 μT, and it gives the calculated accuracy about ±50 μT·m for the 1-st integral.

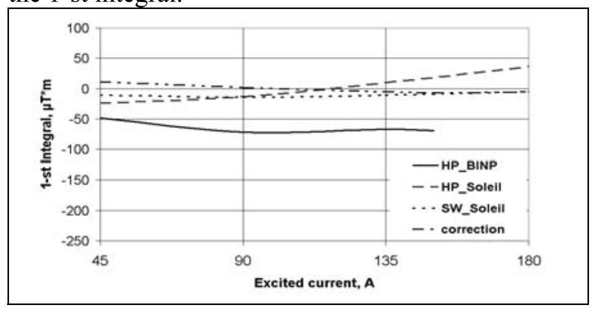

Figure5: HU256 first integral vs. current.

The manufactured and assembled undulators were magnetically measured at BINP. Then the undulators were re-measured after transportation. At SOLEIL site the stretched wire system is applied in addition to Hall measurements to get the 1-st integral parameters with improved accuracy ±10 μT·m. The results of the magnetic measurements of the second undulator are shown in Fig.5.

CONCLUSIONS

The VME-based system for magnetic measurements with Hall sensors is developed. This system is completed specialized device, containing in one VME crate all hardware units, necessary to arrange Hall measurement. Software, prepared for system, allows capturing and storing data, processes it and visualizes results. Besides, this software has convenient graphical interface.

By present time four VME Hall measuring systems are made at BINP. Systems are electrically tested at laboratory and after that used at measurement of real magnets.

Electronics demonstrates accuracy better than $\pm 10^{-5}$. Accuracy for magnetic field measurement depends of sensors and its calibrations. In best case we have absolute accuracy better than ± 20 μT for field range ± 0.5T, typical value is ± 70 μT for fields up to 2T.

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