Magnetometer for new Czech satellite MIMOSA

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Introduction

The new Czech satellite *Mimosa* is designed for measurement of the non-magnetic impacts of the atmosphere and Earth to motion of low-level satellites. The main scientific instrument of the *Mimosa* is high precision accelerometer MAC 03, which has basic resolution 10^{-10} m/s². It is necessary to know the fine orientation of the satellite for precision specification of the acceleration vector (position with respect to the Earth and position in the space – it means turning in the space). The self-contained GPS system is used for definition of position to Earth and precision 3D magnetometer is used for definition of the orientation in the space.

Basic requirements to the magnetometer

Electrical and measurement requirements:
- measurement in 3 axes
- single supply + 6.5V
- resolution of the angular position better then 1^O
- communication protocol RS232
- communication link RS422
- communication speed 57600 b/s
- starting the measurement and data transfer is controlled by main processor of the satellite
- possibility to spread a communication between magnetometer and main satellite system for some other instruction (autocalibration, atc.)

Mechanical requirements:
- temperature range –20 ^{O}C to +60 ^{O}C
- vacuum resistance of all circuits
- radiation resistance of VLSI circuits
- dimensions of the board was assigned

The resolution of the magnetometer in magnetic units is coming out from requirement to resolution better then 1^O and this resolution has to be better then 700 nT.

Full scale of the magnetometer is coming out from next. Maximal value of the magnetic field vector on expected orbital circuit is $\pm$ 65 μT. But we assume large DC interfering magnetic fields from the permanent magnets situated inside of satellite (for example permanent magnets of the steps motors of balance mechanism) and some other interfering fields (fields which are generated by direct currents from solar cells and other fields). For this we chose maximal range of the magnetometer $\pm$250 μT.

Output range from analog part of magnetometer and input range of the A/D converter is from 0 V to +5 V. –250 μT corresponds with 0 V, 0 μT corresponds with 2.5 V and +250 μT correspond with +5 V. From this, conversation constant of the magnetometer is 500 μT/5 V = 1 nT/10 μV.
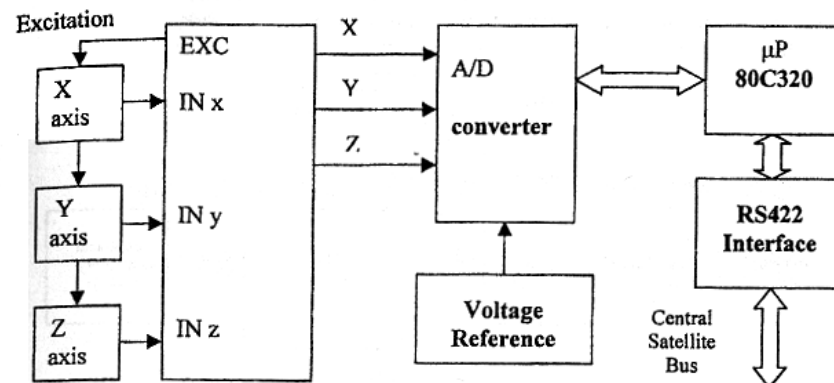
Basic scheme of the magnetometer

Figure 1. Basic block scheme

Figure 1. shows basic block scheme of the "Mimosa" magnetometer. Three flux-gate sensors are excited by the same current. The frequency of the excitation signal is 4 kHz. The second harmonics of the sensor output signals are processed by analog part of magnetometer. The analog part is feedback connecting of the flux-gate magnetometer. Outputs signals from this part are three DC voltages, which are correspond with measuring magnetic fields in three axes.
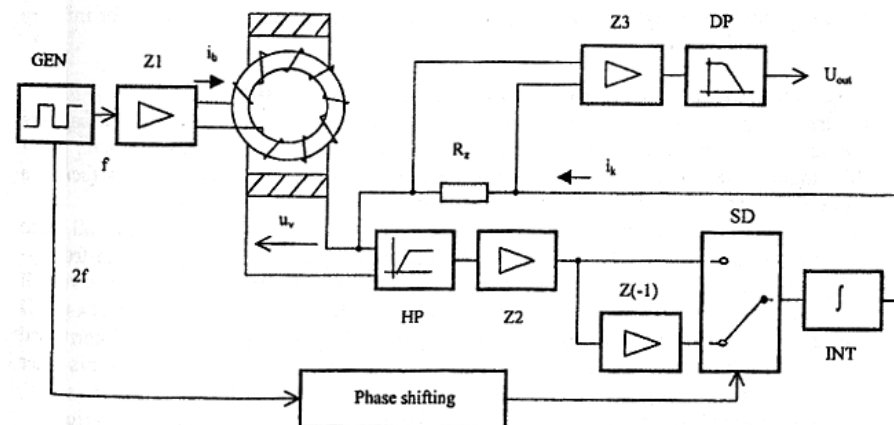

Figure 2. Analog part of the magnetometer

Those three analog DC voltages are converted by high-resolution analog-to-digital sigma-delta converter ADS1211 (Burr-Brown). This converter has four multiplexed analog inputs, synchronous serial data output and nominal resolution 24 bits. The precision voltage reference AD780 is used for generation of reference voltage for A/D converter. Microcontroller is 80C320 (Dallas Semiconductors). It is one member of the I8051 family. The program of the microcontroller is situated in the external program memory

All three sensors were situated in the 6-layer magnetic shield. We measured the noise parameters and long-time stability and functionality of our magnetometer in this configuration.
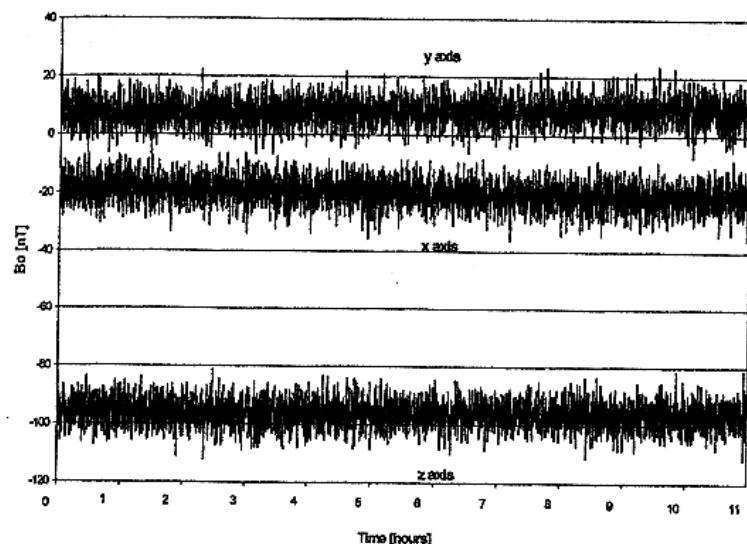
Examples of measured data are in Figure 4.

Figure 4. Noise data of the magnetometer

DC offsets of the measuring signals correspond with offset of the whole magnetometer (offset of the probes and analog part). Dispersion of all three signals is lower than 30 nT peak-to-peak. Other basic parameters of the noise signals are shown in Table 1.

	X axis	Y axis	Z axis
Ustr [V]	2,499801	2,50008	2,499038
Δ Uv [μV]	-199	80	-962
Δ Bo [nT]	-19,9	8	-96,2
Unrms [μV]	45,8	45,4	44,4
Bnrms [nT]	4,6	4,5	4,4
ER [bits]	17,45	17,46	17,49

Table 1. Basic parameters of the noise signals

U_{str} is mean value, ΔU_v and ΔB_o are differences from ideal value (2.5 V corresponded with 0 nT), U_{nrms} and B_{nrms} are RMS values of the noise. ER is the effective resolution of the whole magnetometer (probes, analog and digital parts) and those values were calculated via formula, which is gave in [2].

From the previous data we can conclude, that resolution of the magnetometer is 30 nT and when we convert this resolution into the angle resolution, it is 0.05°. It means, that magnetometer can distinguish satellite turning about 0.05°.

Conclusion

The magnetometer was successfully developed and tested. At present time, it is in lab of our customers for evaluation. The next stage of the project is calibration of the magnetometer and evaluation of its precision when installed inside the satellite body (influence of surrounding magnetic objects). After rocket launch to low orbit, transmitted data will be analyzed in ground-based center. The magnetic data should be used for calibration of microaccelerometric data from the main device of the satellite.

References

[1]   Cerman A.: Magnetometer for Mimosa satellite, Diploma thesis, Dept. of Measurement, CTU in Prague, 2000
[2] ADS1210/11 Users Manual, Burr-Brown, 1997
[3] Ripka P., Kaspar P.: Portable magnetometer, Sensors and Actuators A., 1998