Magnetic Field Measurements in Space: The NewMag Magnetometer

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ABSTRACT

A major payload on the FedSat microsatellite to be launched in late 2001 is the NewMag magnetometer experiment. The experimental flight package will include a Fluxgate magnetometer and a data processing unit. The magnetometer is based on a UCLA space proven design, most recently flown on the POLAR and FAST missions. It has a three-axis orthogonal sensor system mounted on the tip of a 2.55m boom to minimize spacecraft interference. The instrument measures a field range of ± 65000 nT with a bandwidth of 0-50 Hz at a sensitivity of 0.5 nT. Accurate attitude information is provided by an onboard star camera similar to that flown recently on the South African SunSat microsatellite. The Fluxgate magnetometer is being fabricated at UCLA in collaboration with the Space Science group in the Institute of Geophysics and Planetary Physics. Testing and integration is being undertaken by the Newcastle University Space Physics Group and the Systems Engineering Group of the CRCSS in Canberra. This involves ensuring compliance with the NASDA launch requirements, electronic and mechanical compatibility with the Space Innovations Limited (SIL™) Platform, as well as the functional and operational aspects. This paper describes the NewMag system and its capabilities with emphasis on the design, pre-flight testing and operation.

FEDSAT - NEWMAG DESCRIPTION

FedSat is an Australian research microsatellite, measuring 500 x 500 x 500 mm, mass of 58 kg. It is being designed and built by the Cooperative Research Center for Satellite Systems (CRCSS). FedSat is a Low Earth Orbit (LEO) satellite carrying research payloads (NewMag, a GPS experiment, a High Performance Computing Experiment, and Telecommunications experiments. It is due for launch in late 2001 into an 800 km near circular sun synchronous (1030 LT) polar orbit at an inclination of 98.7º. The payloads will be integrated onto a platform constructed by SIL (Space Innovations Limited, UK). After extensive testing and calibration, the completed satellite will be launched by the Japanese Space Agency, NASDA on a HIIA rocket as one of three secondary payloads. Further details of FedSat and the Space Science Program are included in Fraser et al. (2000).

The NewMag experiment will conduct basic research on the structure, dynamics and coupling of the ionosphere to the magnetosphere using magnetic field and GPS derived total electron content measurements. In particular it will contribute to studies of field aligned currents, ELF and ULF plasma waves, and the monitoring and mapping of the geomagnetic field in the Australian region. The NewMag magnetometer is based on the innovative and successful magnetometer which has

provided accurately calibrated measurements on the FAST satellite mission (Elphic et al., 1998). Table 1 lists the specifications of NewMag.

NewMag consists of three components: an analogue electronics unit (ALE); the data processing unit (DPU); and the field sensor, a triaxial fluxgate magnetometer head. The ALE and DPU, shown in Figure 1, and respectively in Figures 2 and 3, are mounted inside a conformally coated aluminum case. This case (see Figure 1) has been specifically designed to meet the thermal dissipation and electromagnetic shielding requirements for operation in space at LEO. The triaxial fluxgate sensors will be mounted on a 2.55m boom, to minimize any magnetic interference produced by the platform and other onboard experiments.

TABLE 1: NewMag Specifications

Dynamic Range	±64,000 nT
Bandwidth	0-50Hz
Absolute Accuracy	±1nT
Sample Rate	10/100 Vectors/s
Noise Level	<0.2nT
Resolution	18 bit with a ±0.2nT digitization window (16 bit with averaging).
Triaxial fluxgate sensors	
Mass	420g
Dimensions	114 x 54 x 61 mm
Power	< 50 mW
Physical Specifications	
Analogue Board (ALE)	600g consuming 1.6W @ 28V
Data Processing Unit (DPU)	600g consuming 2.5W @ 28V

Implementation of the ALE and DPU on separate circuit boards provides isolation for the sensitive analogue drive and sense circuits from the comparatively noisy digital electronics and enables the required operational noise levels to be met. The FedSat platform data handling system (DHS) will provide the relevant command and telemetry interfaces to ground control, as well as 320 Mbyte of storage memory for the system. All data samples will be time tagged by the DPU CPU, and by recording time data from the FedSat system clock (OBET) and the GPS experiment. Time data will be recoverable to within 1msec through data processing on the ground. Information on the orientation of the platform and hence the Fluxgate sensors will be provided by the on-board star camera and ground-based post processing of magnetometer data in conjunction with geomagnetic reference field models.

ANALOGUE UNIT (ALE)

The analogue electronics board shown in Figure 2 consists of three elements:
1) The drive section, including a reference oscillator, high power differential amplifier and modulator to drive the field sensor ring cores into saturation.

2) The three analogue input stages consist of a pre-amplifier, demodulator and integrator. This detects the second harmonic signal in quadrature with the drive frequency. The feedback circuit nulls this harmonic by providing sufficient current to keep the ring cores in zero field. The resulting current indicates the strength of the external field. The low pass filters (integrators) provide output signals with a cutoff frequency at 1000 Hz.
3) The multiplexer (MUX) and analogue digital converter (ADC) which provides a 16 bit digital sample from each of the triaxial sensors as well as monitoring the signals (Russell et al., 1995; 1998).

DIGITAL PROCESSING UNIT (DPU)

This board is shown in Figure 3 and includes a microprocessor controller with data collection and digital filtering (averaging/decimation) capabilities. The onboard 80C86 microprocessor controls the operations of data sampling (at 10 or 100V/s) and filtering in the DPU. The sampled data are temporally stored in the 16kB onboard RAM and are sent periodically to the platform data handling system (DHS) for storage and later transmission to ground. The interface between the DPU and the DHS is via an RS422 link and the UART (Universal Asynchronous Receiver Transmitter) that performs this function is embedded in an Actel Space Qualified FPGA (Field Programmable Gate Array). To meet size and power requirements all the control and interface logic has been implemented by using FPGA's and is the only significant departure from the FAST design (Elphic et al., 1998).

FLUXGATE SENSOR

The fluxgate magnetometer head is fabricated using ring core sensors built at the University of California, Los Angeles (UCLA). Each of the three sensors contains a drive winding and a sense/feedback coil surrounding a magnetically permeable core. Correctly phased currents in the drive coils saturate the ring core twice every drive cycle. External magnetic fields upset the symmetry of saturation, resulting in the generation of even harmonic signals whose amplitude is proportional to the ambient field, in this situation the geomagnetic field (Russell et al., 1995). These signals are detected by the sense coil and used in a feedback system to maintain the core at approximately zero field. Figure 4 shows this function schematically. The drive coils will be driven in series and the sensor assembly will be mounted at the end of a 2.55m boom to provide isolation from the FedSat platform.

NEWMAG SOFTWARE

The software operating NewMag has been developed using FORTH (a compact and self contained language and operating system) and operates as an interrupt driven set of processes. The speed and efficiency of this system allows the use of cost effective proven space qualified processors (an 80C86 in this case) and memory. The onboard software includes a built-in compiler, assembler, interpreter and operating system. The NewMag specific software processes include the command process which control modes of operation and data collection, the I/O process which controls the interface to the SIL platform computer, and the data processes which provide filtering, decimation and buffering of the collected magnetic field data.

NEWMAG GROUND SUPPORT EQUIPMENT (GSE).

The ground support equipment for NewMag (Figure 5) consists of a PC compatible computer running the GSE software, along with hardware control and monitoring facilities (via RS422 and analogue monitoring), as well as a protected power source and a calibrated magnetic field source. The GSE is fully software controlled, written in LabVIEW, a graphical programming language developed by National Instruments), and is designed to provide fully automated remote testing and reporting of the NewMag payload status. After the launch of FedSat, it will be used to provide data collection and operational analysis of the NewMag data.

The NewMag testing process involves functional and environmental testing and calibration at UCLA, and later at AUSPACE in Canberra, and at NASDA in Tsukuba, Japan prior to launch. This poses particular problems for access and testing. To address these problems provision has been made to allow for remote access to NewMag and the associated GSE. Remote operation is facilitated by the use of National Instrument's remote access software, consisting of DataSockets and their Remote Device Access Server running within LabVIEW. This allows for control and monitoring of NewMag and the GSE from a remote machine using an Ethernet TCP/IP connection.

NEWMAG TESTING

To test and ensure the integrity of NewMag during assembly, integration and test (AIT), provision has been made to operate the magnetometer sensors within a programmable range of test fields. In the GSE, the fluxgate sensors are mounted inside a shielded container (flux tank) with an induction coil driven by the GSE system to provide the programmable test magnetic field magnitude and frequency. This allows for automatic testing of functionality and the calibration of the sensors using the associated Newcastle University test software (NewT). The tests that are performed are listed in Table 2.

TABLE 2: NewMag Performance Tests

Dynamic Range and linearity	-64knT - 64knT
Noise level	
Temperature response	-20C - +50C
Time/vibration stability	TBD
Clock (timing) drift	< 50msec/orbit
Calibration against a reference field	3 axis using flux tank (to 1nT)
Frequency response	0-1kHz

Tests will also be performed on the functionality of the onboard software, and will include the upload of software patches, protocol checks, mode changing and remote power switching. These test results are all logged and stored as raw data and automatically provide printed reports and also provide the required calibration data for future reference.

CONCLUSION

For space qualification including AIT, NewMag has extensive design, construction, and test requirements. This will ensure that at launch NewMag will have been tested and satisfied all the environmental conditions it will experience, particularly on launch. Establishing a simple automated, remotely operated GSE providing an efficient and comprehensive test procedure capable of guaranteeing minimal risk in launch and on orbit.

REFERENCES

Elphic, R. C., J. D. Means, R. C. Snare, R. J. Strangeway, L. Kepko, and R. E. Ergun, Magnetic field instruments for the FAST auroral snapshot explorer, *Space Sci. Rev.,* in press, (2000).

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FIGURE CAPTIONS

Figure 1. The NewMag payload electronics box.

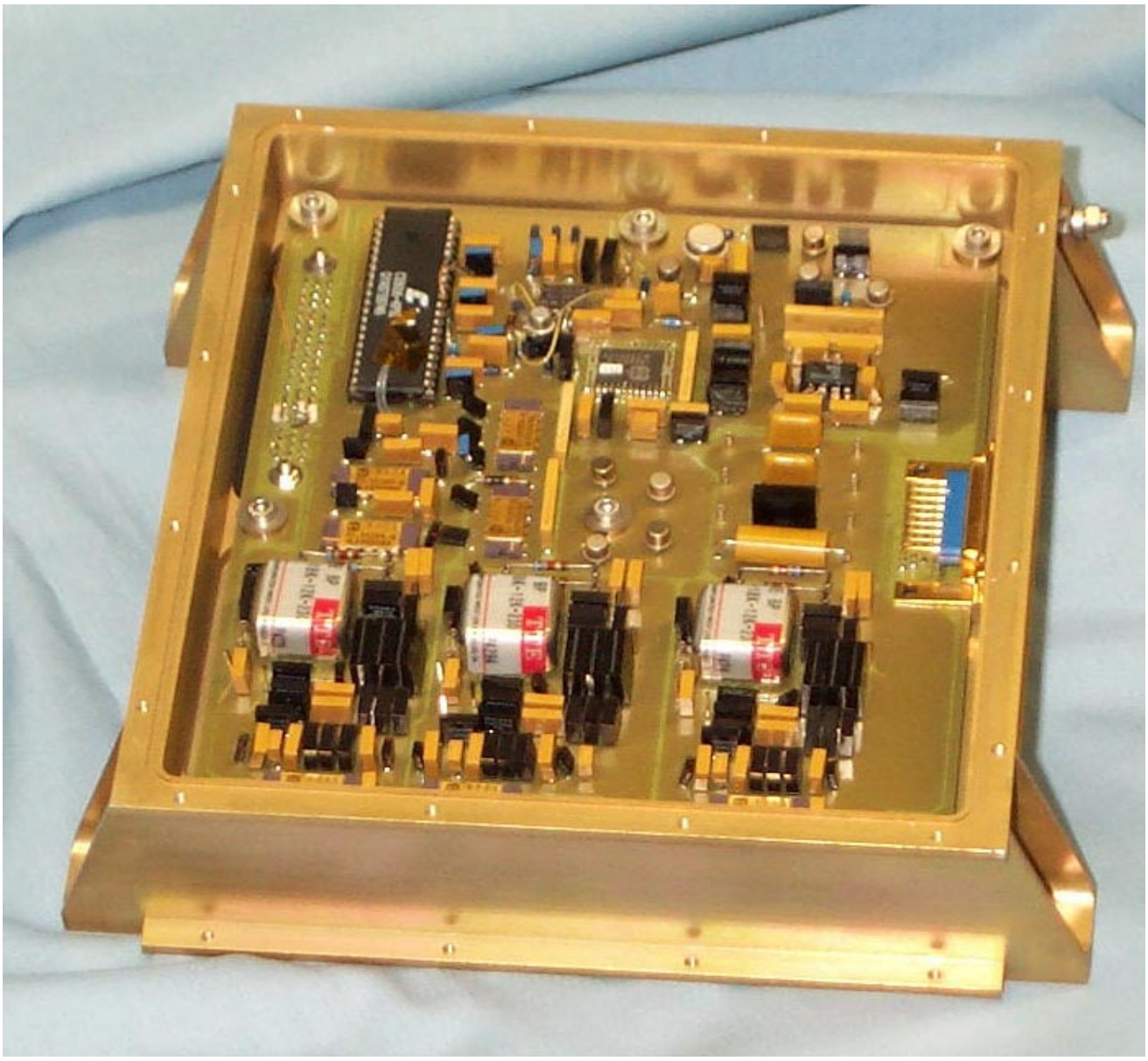

Figure 1

Figure 2. The Analogue Electronics Unit (ALE).

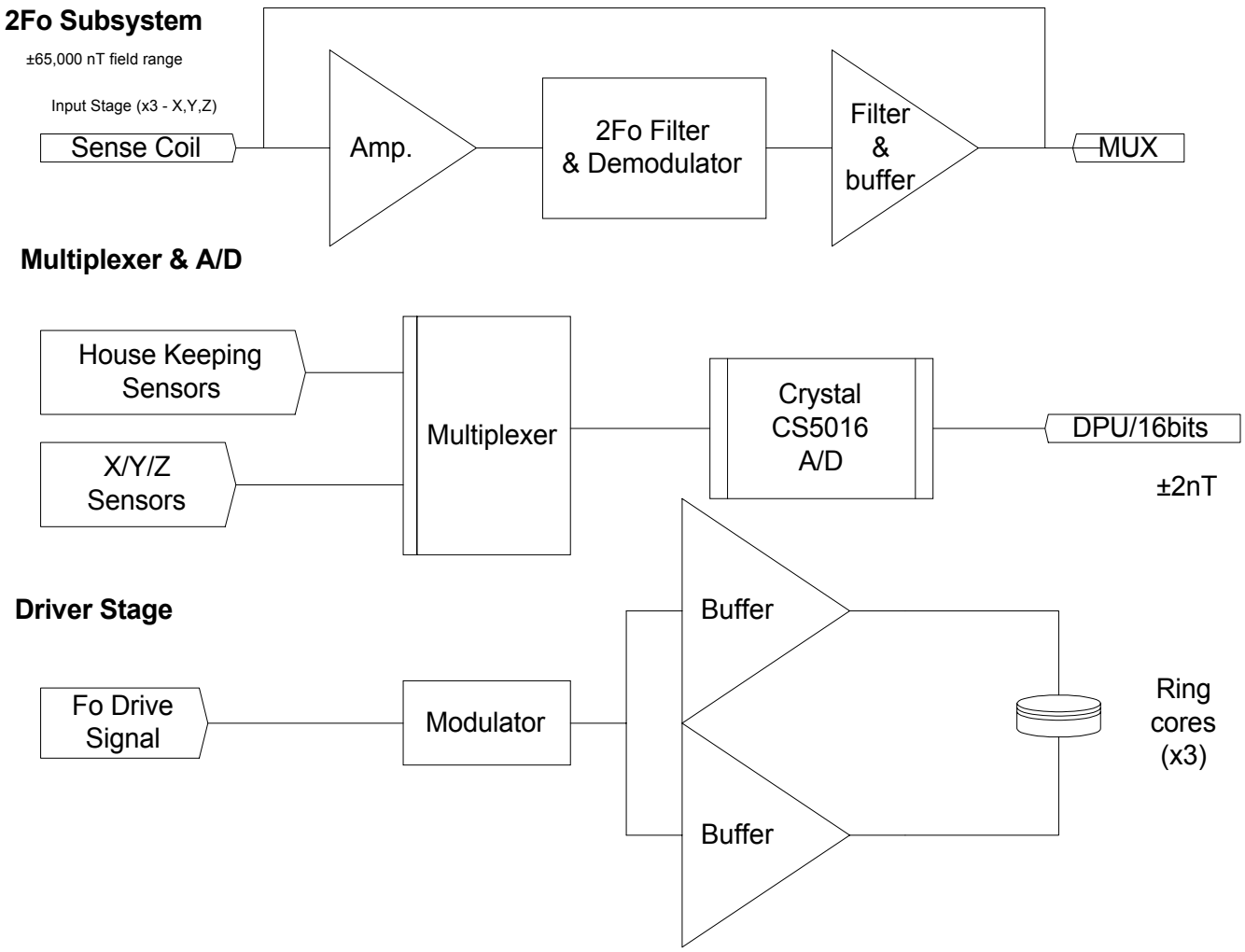

Figure 2

Figure 3. The Data Processing Unit (DPU).

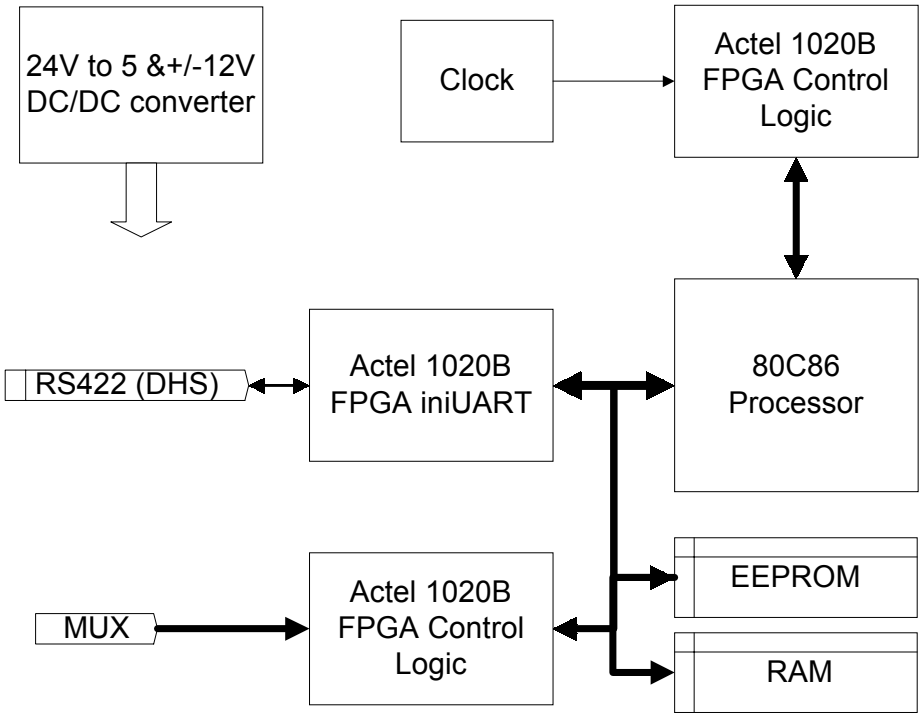

Figure 4. Fluxgate magnetometer schematic.

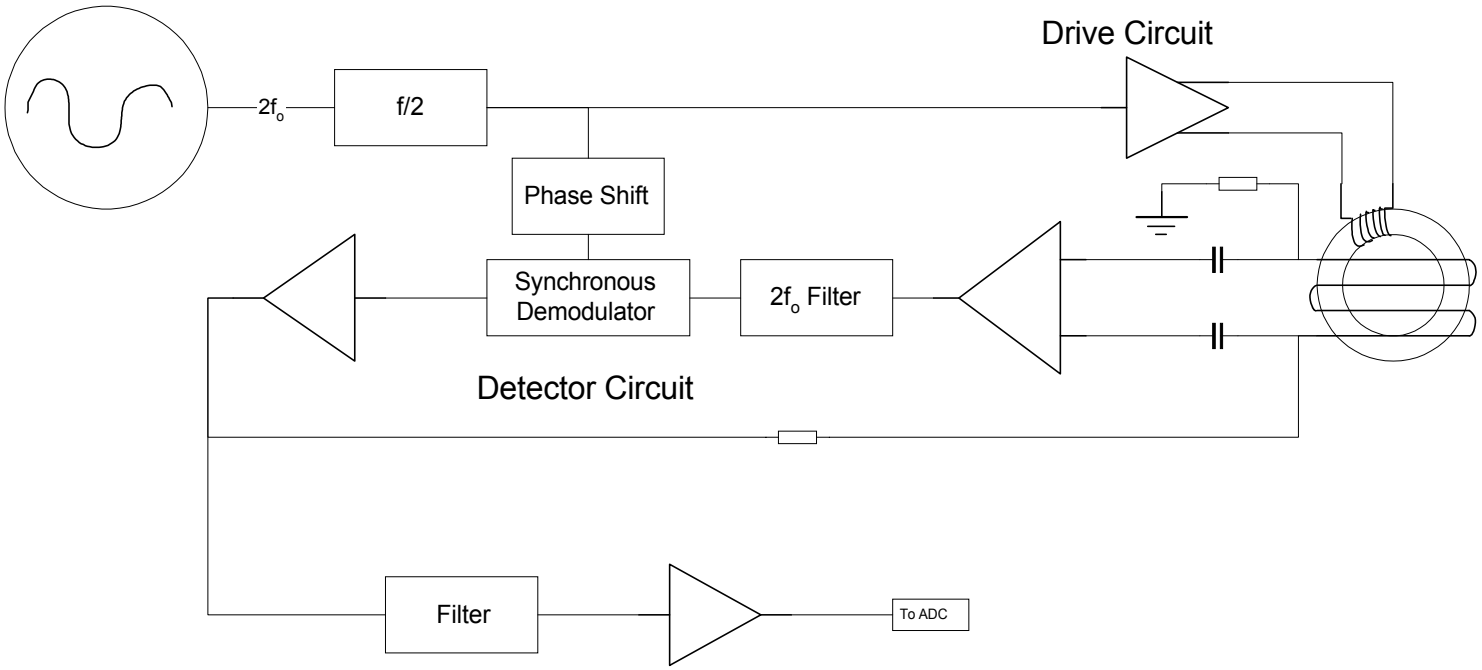

Figure 5. Ground Support Equipment (GSE).