ADAPTIVE AEROMAGNETIC REAL-TIME COMPENSATOR

Magnetometer interface counter for one sensor

Real-time compensation

Magnetics & basic general-purpose data acquisition

Compact, light, low power – ideal for UAV applications

< 1.8 Kg; 133 x 133 x 216 mm
(4.0 lb; 5¼ x 5¼ x 8½ in)

+28 VDC, 3 A

- Front-end sampling rates up to 1280 Hz
- Magnetometer processor: 0.32 pT resolution, < 0.1 pT system noise, ±10 ppb temperature stability
- Proven, extremely robust compensation algorithms (AADCII legacy)
- Adaptive signal processing techniques
- User may customize Front End processing to specific installation requirements
- Interface for external GPS receiver
- Data output and recording (embedded Flash memory): 10, 20, 40 Hz or external trigger
- Post-flight compensation & analysis functions
- Dynamic compensation of on-board electronics
- Real-time graphical output and user interface on any external display
- Two analog inputs for radar/laser altimeter, etc.
- Data acquisition via Ethernet
- Full monitoring/control from any Windows device (via Ethernet, or remotely via internet)
- Features targeted to UAV applications
- State-of-the-art HW & FW architecture based on advanced 32-bit processors
- Real-time operating system (RTOS): QNX 6.5
**Aeromagnetic Compensation**

The quality of the data collected in aeromagnetic surveys is largely dependent on the quality of compensation. Despite the outstanding sensitivity of modern magnetometers, in the absence of good compensation, anomaly signals which fall off as the third or fourth power of distance, can be completely masked out by the interference of the nearby magnetics of the aircraft.

The aircraft's magnetic interference is related to its motions about its principal axes. A mathematical model may be built to accurately represent the aircraft's magnetic signature. Careful optimization and implementation of this model, within the framework of sophisticated hardware and firmware technologies, can lead to real-time compensation that effectively eliminates the aircraft's magnetic interference.

The RMS Instruments' AARC51 Adaptive Aeromagnetic Real-Time Compensator provides real-time compensation of local magnetic interference for inboard magnetometer systems in fixed-wing aircraft, helicopters, or UAVs to the point where the full resolution of modern high sensitivity magnetometers can be utilized. The compensation accounts for the effects of permanent and induced magnetism, Eddy currents, and heading errors from the sensors.

**Benefits of real-time compensation**

State-of-the-art aeromagnetic surveying requires real-time monitoring of compensated data, so that problems are identified immediately and are promptly corrected. The magnetic signature of typical survey aircraft can be rather unstable and change in-flight; detecting these changes while monitoring uncompensated data is practically impossible. By eliminating costly and error-prone post-flight processing, real-time compensation further contributes to increased productivity, efficiency and cost-effectiveness.

**Calibration and solution**

The AARC51 uses a 3-axis fluxgate magnetometer to monitor the aircraft's position and motion with respect to the ambient magnetic field while flying a set of standard maneuvers of rolls, pitches and yaws in orthogonal headings. During the calibration mode of approximately 6-8 minutes, the positional data together with the magnetometer sensor readings are utilized by a sophisticated model to arrive at a solution of approximately 30 terms.

The solution is a comprehensive mathematical model that accurately describes the magnetic interference of the moving aircraft. It is calculated instantly, upon termination of the calibration maneuvers. It is immediately available for use in compensation mode or for further analysis and comparison with other solutions.

With the AARC51 there is no need for any post-flight software. The system uses the full 360° pattern to obtain a robust solution. If necessary, in the event full 360° signal acquisition is not possible, the AARC51 allows calibration for each active zone, and a corresponding solution. Furthermore, any set of such partial calibrations can also be readily combined to produce a single robust solution for all of the sensor's active zones.

**Compensation**

In compensation mode measured values of the total field high-sensitivity magnetometer are corrected in real-time using one of the solutions previously obtained. Compensated and uncompensated signals along with the 3-axis vector magnetometer and other ancillary data, are available for real-time recording and monitoring.

**Adaptive compensation**

The AARC51 incorporates sophisticated adaptive signal processing techniques that allow the system to continuously "learn" from input signals, and adapt the solution coefficients for optimum compensation. This can lead to improved band-passed compensation (up to several times lower residual errors), and simplified calibration procedures. Other novel approaches are continuously being developed and can be readily incorporated into the system thanks to its flexible architecture.

Left – Bandpassed uncompensated and compensated data for a full calibration flight (6 minutes). The uncompensated waveform clearly shows the aircraft interference on the four headings. Performance indicators: $\sigma_{\text{uncomp}} = 0.5502 \text{ nT}$, $\sigma_{\text{comp}} = 0.0282 \text{ nT}$, $IR = 19.5$. (Waveforms are offset for clarity.)

Right – Wideband uncompensated and compensated waveforms. (Mean value subtracted for clarity.)
Dynamic compensation of OBE systems
The AARC51 incorporates new technology that allows real-time dynamic compensation of the effects of DC currents from on-board electronic (OBE) systems, such as radios, control systems and other instrumentation. OBE compensation simplifies operational requirements, increases robustness and tolerance to electrical sources, and improves overall compensation performance. The technology works with fixed- and variable-current devices, for up to two independent OBE systems.

System Architecture
RMS Instruments’ compensation technology is based on a flexible architecture with dual 32-bit processors. It includes state-of-the-art COTS (industrial-grade) electronics, and a proprietary magnetometer interface with excellent accuracy. Front End sampling rates up to 1280 Hz and finely-tuned transfer functions deliver outstanding anti-aliasing characteristics, and may be customized by the user to the specific requirements of an installation.

The main program and real-time operating system (RTOS) reside in (solid-state) Flash memory. The RTOS is QNX 6.5 (or later). This is a deterministic and extremely reliable operating system tailored to mission-critical applications.

A three-axis fluxgate (vector) magnetometer is included with the system. Signals are processed using a high-resolution (16-bit) A/D converter.

The software includes an easy-to-use graphical user interface, and a rich set of utilities to analyze data and help troubleshoot aeromagnetic installations.

Interface for external GPS receiver
The AARC51 includes an interface for an external (user-supplied) GPS receiver that may act as the source of all timing within the system. GPS information is appended to recorded magnetics data. The external receiver should have at least one COM (RS232) port that can be configured to transmit NMEA standard GGA sentences at a rate of up to 10 Hz, and a PPS (pulse-per-second) trigger output.

Post-flight compensation & analysis
Advanced embedded functions allow post-flight survey compensation, in the event a suitable calibration was not available at time of flight. This complements the fundamental real-time compensation function, key for productive and efficient airborne magnetometry. Also included are functions for in-depth analysis of calibration data, and frequency-domain analysis.

General-purpose data acquisition
The AARC51 supports data acquisition via 1-Gbps Ethernet (TCP/IP packets), and includes two differential, high-resolution analog inputs to complement magnetics data – e.g., radar/laser altimeter, etc.

UAV Applications
The AARC51 is ideally suited to Unmanned Aerial Vehicle (UAV) applications because of its light weight, compact package, and low power consumption.

In typical UAV use the unit would be pre-configured on the ground at the start of a project, set up to automatically start data acquisition, compensation and recording on power up. The configuration is easily carried out either using a laptop/computer via Ethernet, or by attaching any display/monitor with a standard analog (RGB) interface and a USB mouse/keyboard. During actual surveys the AARC51 is essentially a “black box” continuously recording in embedded Flash memory magnetics data (raw and compensated) as well as other ancillary data. Upon landing, the data are extracted from the system through a USB Flash memory device or via Ethernet.

For optimum performance a suitable calibration flight must be carried out as far as possible from any geological and/or cultural interference. This presents unique challenges in UAV systems, without an operator on-board to control the starting and ending points of the calibration (or learning) mode of operation. The AARC51 provides two comprehensive approaches to automate this process: time-framed calibrations (TFC), and altitude-controlled calibrations (ACC). With TFCs the operator pre-defines a specific time window after power up, during which calibration maneuvers must be flown. With ACCs a (voltage) control signal from an altimeter controls the start and end of calibrations at operator pre-defined altitudes.

Remote control from Windows
A remote connectivity tool for the AARC51 allows users full control and operation of the unit from a remote Windows-based system, across an IP network.

The user interface of the AARC51 is seamlessly replicated in the Windows-based computer. The mouse and keyboard attached to the computer have the same effect as if they were directly connected to the AARC51.

This technology facilitates flexible architectures for complex systems that incorporate the AARC51. A single computer/laptop can be used to control and operate the AARC51 and other instruments (e.g., gamma-ray spectrometer, gravity system, etc.). Any other Windows applications can also be running simultaneously (e.g., navigation software). This remote connectivity is also very useful for training and remote support (from any location, via Internet).
AARC51 SPECIFICATIONS

Magnetometer Input:
One high-sensitivity magnetometer:
Cs: Typ. 70 kHz – 350 kHz

Magnetic Field Range:
Per the magnetometer's range; e.g.:
G-822A, G-823A: 20,000–100,000 nT
CS-3, CS-L, CS-VL: 15,000–105,000 nT

Front End (FE):
Time base: > 100 MHz, OCXO
Resolution: 0.32 pT
System noise: σ < 0.1 pT
Temperature stability: ±10 ppb
Sampling rate: 160, 640, 800 or 1280 Hz – user-selectable
Transfer function (bandwidth): 1.6 Hz, 3.25 Hz, 6.4 Hz, 9.8 Hz, 20 Hz, 0.16 FSH or Custom – user-selectable

Compensation Performance:
Fixed-wing, helicopter:
IR (total field): 10–20, typical
(Further improvement possible with adaptive compensation, 2X to 5X typical, band-passed TF)
UAV: t.b.d.

Compensation Accuracy:
Fixed-wing, helicopter:
σ = 20 pT, full flight envelope, 0–1 Hz
UAV: t.b.d.

Optional Filter (Host):
User-selectable, 0.4 – 3.0 Hz BW

Calibration Duration:
6–8 minutes, typical

Vector Magnetometer:
Included with the AARC51
3-axis fluxgate
 Oversampling, 16-bit, self-calibrating ADC

OBE Compensation:
Dynamic compensation of up to 2 independent on-board electronic systems

Data Output & Recording:
Rate (FSH): 10, 20, 40 Hz, external trigger, external-PPS – user-selectable
Ethernet: TCP/IP packets, ASCII/Binary
Recording media: embedded Flash memory (≥ 2 GB), USB Flash disk
External display (analog RGB)

Event Inputs:
PPS trigger signal from external GPS
Two general-purpose latched event inputs
LS-TTL levels, edge-sensitive
Event tags included with output data
Accuracy: per Front End sampling rate

Raw Data Logging:
At Front End sampling rate
1-MB buffer

FE-Sampled Analog:
Two differential inputs
16-bit resolution, self-calibrating ADC
Input range: ±5 Volts
Input resistance: 1 MΩ, typical

Data Acquisition via Ethernet:
10/100/1000Base-TX
TCP/IP
Sampling & recording: FSH or submult.

Remote Control:
From any Windows-based computer, via IP ntwk. over Ethernet – replica of AARC51's user I/F on computer

Indicators, General-Purpose I/O:
1 LEDs for mag. input status
2 LEDs for Front End status
Three USB 2.0
10/100/1000Base-TX Ethernet (RJ45)
Analog RGB (15-pin D-sub)

External GPS Receiver Interface:
Interface to any GPS receiver that outputs NMEA GGA packets via serial (RS232) port (up to 10 Hz), and PPS trigger (LS-TTL or LV-TTL)
Magnetics data tagged with GPS time, lat., lon., altitude, and quality indicator

Post-Flight Compensation:
Advanced analysis functions on standard system-recorded d-files:
Post-flight compensation
Calibration/solution robustness analysis
Frequency-domain analysis

Power:
Nominal: +28 VDC, 3 A
(Total power requirement, including one magnetometer sensor)
Range: +19 to +36 VDC
Absolute maximum: +50VDC, < 100 msec

Environmental:
Operating Temperature: 0 to +50°C
Storage Temperature: –20 to +55°C
Relative Humidity: 0 to 99%, non-condensing
Altitude: 0–6,000 m (0–20,000 ft)

Size (W x H x D):
133 x 133 x 216 mm, (5¼ x 5¼ x 8½ in)

Weight:
< 1.8 Kg (4.0 lb)
(Excluding external cables, mounting hardware & sensors)

Notes:
[1] Per manufacturer's specs. at print time: G-822A, G-823A (Geometrics), CS-3, CS-L, CS-VL (Scintrex).

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Specifications subject to change without notice
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For additional information on these and other products, contact:

Distributed By:

Tel: (905) 677-9033  Fax: (905) 677-9030
Web: http://www.rmsinet.com
E-mail: rms@rmsinet.com