# ADAPTIVE AEROMAGNETIC REAL-TIME COMPENSATION FOR UAVs

***Magnetometer interface counter for 2 sensors***

***Real-time compensation: two total-fields and true-gradient***

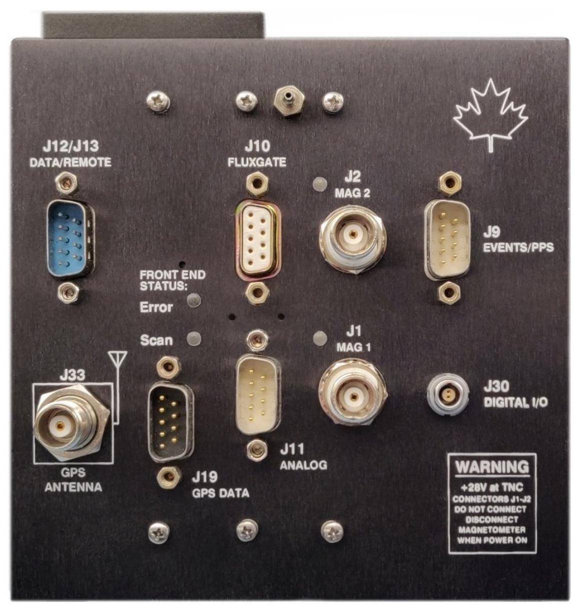
***Magnetics & general-purpose data acquisition & recording***

***Embedded GPS receiver (optional)***

***Compact, light, low power –***

***133 x 133 x 216 mm***
***+28 VDC (19–36 VDC), 3.5 A***
***< 2.0 Kg***

- *Front-end sampling rates up to 1280 Hz*
- *Magnetometer processor: 0.32 pT resolution, < 0.1 pT system noise, ±10 ppb temp. stability*
- *Proven, highly-robust compensation algorithms (AADCII legacy)*
- *Adaptive signal processing techniques*
- *User may customize Front End processing to specific installation requirements*
- *Interface for external GPS receiver (standard); embedded GPS receiver option (single-, dual- or triple-frequency)*
- *Recording up to 160 Hz: complete raw, pre-processed and compensated data sets*
- *Post-flight compensation & analysis functions*
- *Dynamic compensation of on-board electronics*
- *Gating of magnetometer readings for concurrent use with EM systems*
- *Real-time graphical output and user interface on any external display*
- *Two general-purpose analog inputs (e.g., radar altimeter), two assigned to embedded barometric-pressure & temperature sensors*
- *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 64/32-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 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' AARC52 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.

### The importance 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 mode, model and solution

The AARC52 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. This *calibration* process, which typically takes 6-8 minutes, yields a (mathematical) *solution* that models the aircraft's magnetic signature. The solution is calculated instantly, upon termination of the calibration maneuvers. It is immediately available for use in compensated (i.e., survey) mode, or for further analysis and comparison with other solutions.

With the AARC52 there is no need for any post-flight software. The calibration is effective for the full 360º range of headings. At very low dip angles, *partial calibrations* for each active zone can be readily combined to produce a single robust solution for the full 360º range.

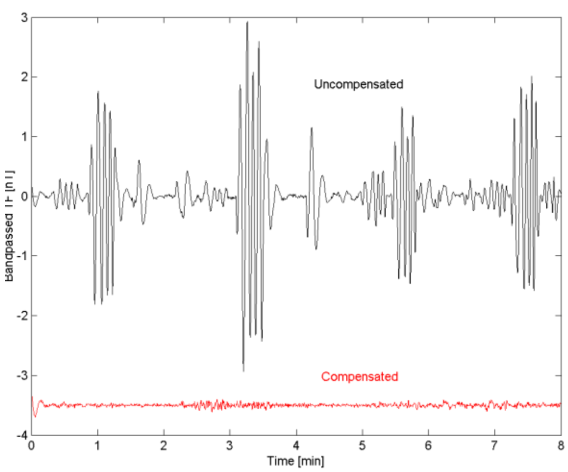
### Compensation – total fields & gradients

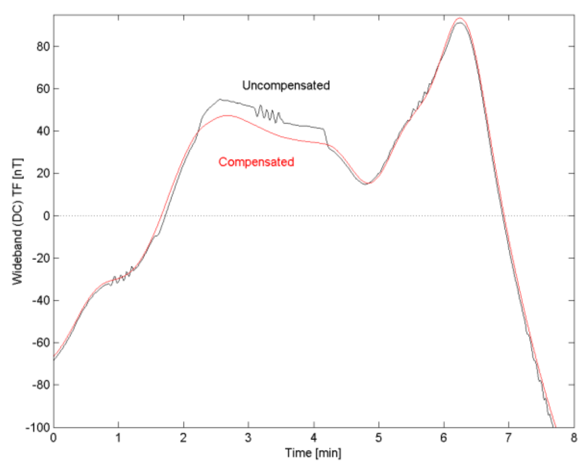
In *compensation* mode the total-field (TF) high-sensitivity magnetometers, as well as the associated gradient, are compensated in real-time using the last solution obtained (or any other solution previously archived). Compensated and uncompensated data, along with the 3-axis vector magnetometer and other ancillary data, are monitored and recorded in real-time.

Importantly, the system provides *true* gradient compensation: an independent calibration solution is calculated for the gradient.

### Adaptive compensation

The AARC52 incorporates adaptive signal processing techniques that allow the system to continuously "learn" from input signals, and adapt the solution coefficients for optimum compensation. The underlying recursive algorithm has significant computational advantages over the "conventional" alternative, and leads to improved band-passed and gradient compensation. Adaptive compensation substantially eases calibration procedures, and yields solutions that remain close to optimum as the aircraft's magnetic signature changes with time.




*Left – Bandpassed uncompensated and compensated data for a full calibration flight (8 minutes). The uncompensated waveform clearly shows the aircraft interference on the four headings.*
*Performance indicators: $\sigma_{uncomp}$ = 0.5502 nT, $\sigma_{comp}$ = 0.0282 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 AARC52 incorporates new technology that allows real-time dynamic compensation of the effects of DC currents from on-board electronic (OBE) systems, such as avionics, hydraulics, 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*

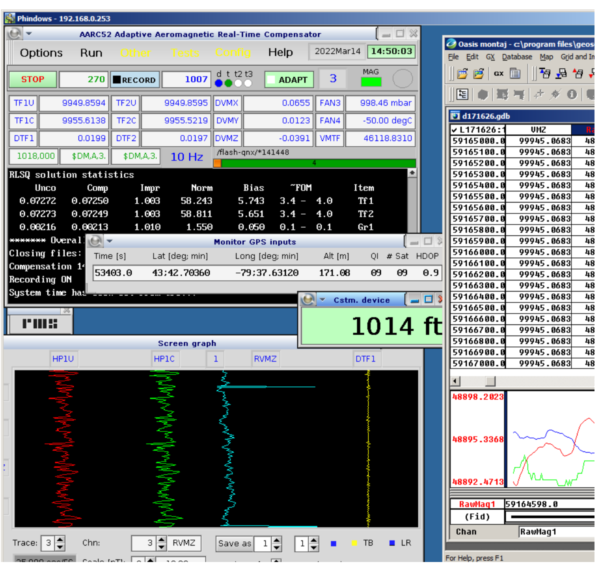
RMS Instruments' compensation technology is based on a flexible architecture with dual 64/32-bit processors. It includes state-of-the-art COTS (industrial-grade) electronics, and a proprietary magnetometer interface with excellent accuracy.

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 memory. The RTOS is QNX 6.5 (or later), 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.




### Remote control from Windows

A remote connectivity tool for the AARC52 allows users full control and operation of the unit from a remote Windows-based system, across an IP network.

The user interface of the AARC52 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 system.

This technology facilitates integration of complex systems, with a single computer/laptop being used to control and operate the AARC52 and other instruments, while simultaneously running complementary software.

### GPS receiver

An interface for an external GPS receiver is standard. The AARC52 supports also an embedded GPS receiver (optional). A variety of receivers are available to satisfy different requirements in accuracy. One port on the receiver is used internally; an additional two ports are accessible by the user (for example, to interface to a navigation system). GPS data are appended to recorded and transmitted magnetics data packets. Timing throughout the system is tied to the PPS trigger from the GPS receiver.

### 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 AARC52 supports data acquisition via Gigabit-Ethernet (with multiple logical connections), and includes two general-purpose differential, high-resolution analog inputs (e.g., radar/laser altimeter) and two dedicated to embedded pressure and temperature sensors.

The system includes flexible means for real-time monitoring of the data streams acquired via Ethernet, as well as the analog inputs.

## *UAV Applications*

The AARC52 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 is pre-configured on the ground at the start of a project, set up to automatically start data acquisition, compensation and recording on power up. This is easily done using a laptop/computer via Ethernet, or by attaching a display and mouse/keyboard. During surveys the AARC52 is essentially a “black box” continuously recording in an embedded solid-state drive (Flash) magnetics data (raw and compensated), GPS and other ancillary data. Upon landing, the data are extracted from the system through a USB memory stick 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. Without an operator on-board this presents unique challenges in UAV systems. The AARC52 allows real-time command and control from the ground with a long-range wireless Ethernet link onboard the UAV. Alternatively, it provides two comprehensive approaches to automate the calibration 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 the start/end of calibrations may be controlled through the embedded barometric pressure sensor (or an external sensor/altimeter), or GPS altitude.

## AARC52 SPECIFICATIONS

***Magnetometer Inputs:***
Two high-sensitivity magnetometers:
Cs: Typ. 70 kHz – 350 kHz

***Magnetic Field Range:***
Per the magnetometer's range; e.g.: [1]
G-822A, G-823A: 20,000–100,000 nT
CS-3, CS-L, CS-VL: 15,000–105,000 nT

***Gradiometer:***
True gradient compensation – independent model/solution calculated for the gradient

***Front End (FE):***
Time base: > 100 MHz, OCXO
Resolution: 0.32 pT [2]
System noise: σ < 0.1 pT [3]
Temperature stability: ≈ ±10 ppb [4]
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$F_{SH}$ or Custom – user-selectable

***Compensation Performance:***
Conventional (manned) fixed-wing, helicopter:
- σ ≈ 20 pT, full flight envelope, 0–1 Hz
- IR, total fields (TFs): 10–20, typical
- IR, gradient: 20–100, typical
- Adaptive mode: Recursive approach with user-selectable gain; up to 2–5X further improvement (typical), band-passed TFs & gradient.

UAV: Consult RMS Instruments

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

***Calibration Duration:***
6–8 minutes, typical

***Vector Magnetometer:***
Included with the AARC52
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:***
$F_{SH}$: 10, 20, 40, 80, 160 Hz (GPS-PPS or internal synch.); external-trigger
Serial port: 115.2 kbps, ASCII/Binary
Ethernet: TCP/IP packets, ASCII/Binary
Recording media: embedded Flash SSD (≥ 32 GB), USB Flash disk
External display (VGA)

***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

***Embedded Barometric Pressure & Temperature Sensors:***
Differential inputs, 16-bit ADC
600 to 1100-mbar range; ±5 mbar total accuracy
–50 to +100°C range; ±1°C abs. error

***EM Gating:***
For concurrent use with EM systems
LS-TTL input with pull-up

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

***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
Real-time, streaming data (TCP/IP)
Three independent logical connections
Sampling & recording: $F_{SH}$ or submult.

***Synch. to External Devices:***
One pulse-train output
Rate: $F_{SH}/x$, with $1 \le x \le 255$
Low-going pulses, > 10-µsec width

***Remote Control:***
Optional: From any Windows-based computer, via Ethernet – full user I/F
Via serial (RS232) port – ASCII cmnds.

***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)
VGA video (15-pin D-sub)

***GPS Receiver:***
Standard: Interface to any GPS receiver with NMEA GGA output via serial port (RS232, 115.2 kbps, up to 10 Hz), and PPS trigger (LS-TTL or 5V-tolerant LV-TTL)
Optional: Embedded GPS receiver; typically, dual-frequency Novatel OEM7 series supporting L-band corrections
Magnetics data tagged with GPS time, lat., long., altitude, and auxiliary data
Up to 10 Hz

***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, 3.5 A
(Total power requirement, including magnetometer sensor(s) [5])
Range: +19 to +36 VDC
Absolute maximum: +50VDC, < 100 msec

***Environmental:***

**Operating Temperature:** –10 to +50ºC (0 to +50ºC with HW Rev. < 3.00)

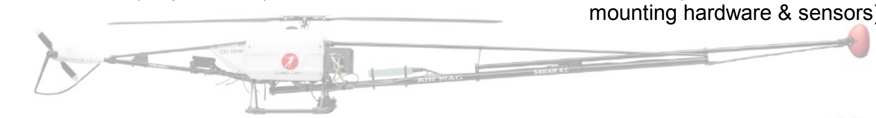
**Storage Temperature:** –20 to +55ºC

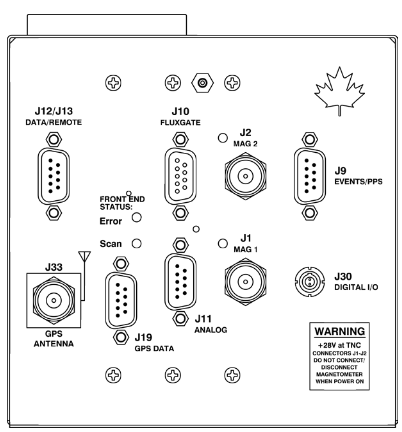
**Relative Humidity:** 0 to 99%, non-condensing

**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:** < 2.0 Kg (4.4 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).
- [2] 1.6-Hz BW, 625-ms integ.
- [3] Typical; 1.6-Hz BW, 625-ms integ., 10 Hz.
- [4] Within operating temperature range. Over –20 to +70°C, < ±35 ppb.
- [5] Per Geometrics G822A-type sensors. May vary for other sensors.

*Specifications per Host FW ≥ RMS11122-03-E, FE FW ≥ RMS1877-05-B, HW Rev. ≥ 3.20, and subject to change without notice – **Jun 2023**.*



*For additional information on these and other products, contact:*

*Distributed By*:

**RMS INSTRUMENTS**
*For Geophysical Exploration*

6877-1 Goreway Drive
Mississauga, Ontario
Canada L4V 1L9

Tel: (905) 677-5533
Fax: (905) 677-5030
Web: http://www.rmsinst.com
e-mail: rms@rmsinst.com