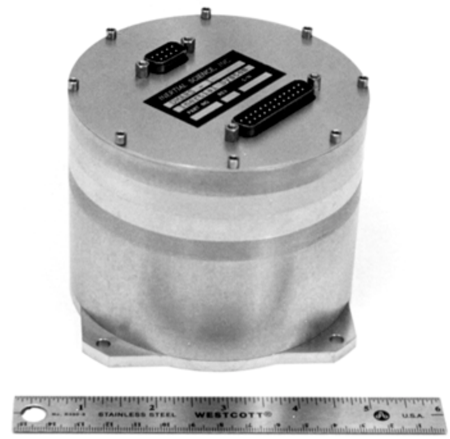
INERTIAL SCIENCE, INC.

DIGITAL MINIATURE ATTITUDE REFERENCE SYSTEM
DMARS-i



Description

DMARS-I is a 6-degree of freedom motion sensing Inertial Measurement Unit (IMU). This IMU consists of 2 each of 2 axes dynamically tuned gyroscopes (DTG) and 3 of single axis pendulous linear accelerometers and a computational electronics.

A Gyro servo and spin electronics actuate a DTG to sense the input angular rates and transform into analog signals. Meanwhile the accelerometers send out an analog signal proportional to the input linear acceleration. These sensed analog signals are digitized by 24 bit converters.

The computer compensates errors in the sensors. They are scalefactor, bias, misalignmnet angles, mass imbalance and other dynamic and temperature related errors. The compensated informations are shipped out via a serial communication link. The output consists of BIT, Dqx, Dqy, Dqz, DVx, DVy and DVz with 200 frames per sec.

DMARS-I Background

The **DMARS-I** platform, jointly designed by **Inertial Science, Inc.** and **Sandia National Laboratories**, is a full-featured low-cost inertial navigation system which is specially designed to function in various missile and rocket applications. **DMARS-I** is our third generation navigation system and evolved from our **DMARS-R** (Digital Miniature Attitude Reference System). The **DMARS-R** has been successfully flown in various launch systems as **SPINRAC**, **MAXUS**, **POIVRE**, **CHOPS**, **ET & CE**, **HERA**, **TMTS**, **KSR-II**, and most recently **RED CROW** (1998) conducted by **Sandia National Laboratories**.

The improvements are in size, power consumption, performance, maintainability, reliability, and most importantly in ownership cost (much lower than **DMARS-R**). Designing the **DMARS-I** in a smaller size, without compromising the performance will reduce material and production cost.

DMARS-I is mechanized using two each **Dynamically Tuned Gyros** (DTG) and three each pendulous **accelerometers** with self – contained servo electronics. The instrument consists of gyros and accelerometers is mounted on the sensor block which is covered with a sealed housing. This is referred to as the Inertial Measurement Unit (IMU). A separate housing contains the electronics which consists of the required electronics for the unit, the **microprocessor**, associated memory and I/O. The electronics assembly is referred to as the Navigation Processor Unit (NPU). The IMU and NPU can be mounted together to form a single unit or separately to multiple units.

All body rates are digitally compensated for bias, scalefactor, misalignment, and temperature effects, from the digitized gyro and temperature information. The body angles are computed by using quaternion integration with 100Hz iteration rate.

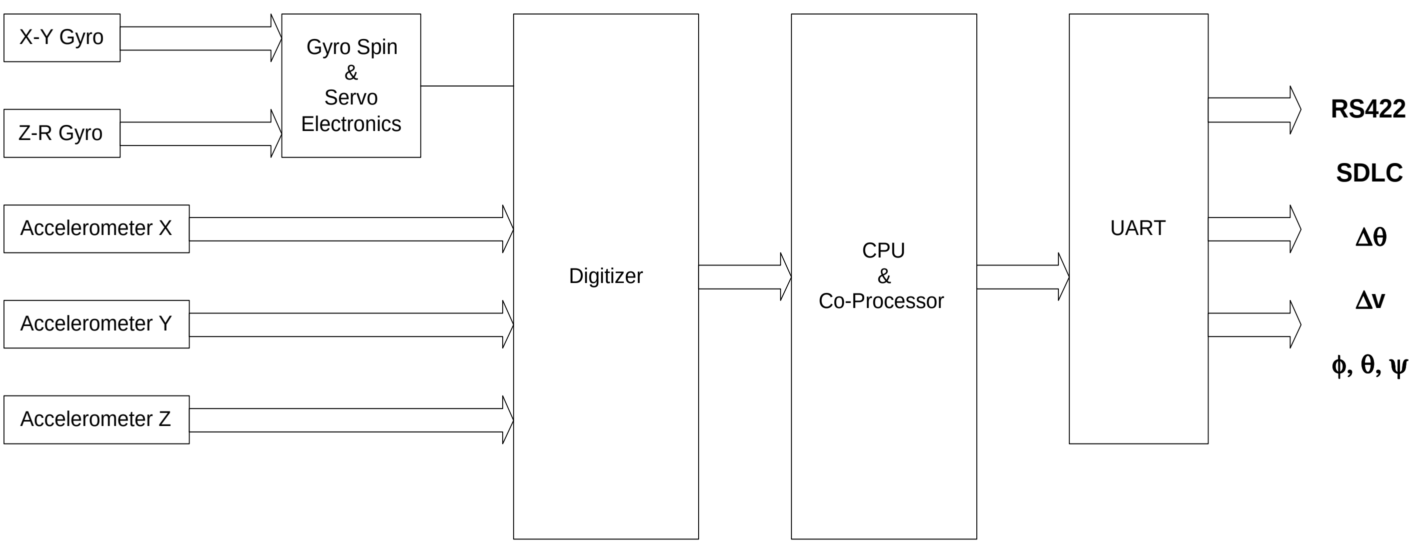
Features

- **Strap-down Inertial Navigation System**
- **Developed by Sandia National Lab. & *Inertial Science, Inc.***
- **Digital processing**
- **Versatility**
- **Modular design**
- **Reliability and increased MTBF**
- **High Accuracy**
- ***Small size and low power consumption***
- **Low cost**
- ***Enhanced navigation and flight control***
- ***GPS-INS integrated navigation system***
- **Low Noise**
- **Excellent in run stability**

Typical Applications

- **Aircraft & Missile flight control**
- **Rate and Attitude control of Sounding Rocket**
- **SAR (Synthetic Aperture Radar)**
- **GPS/INS Applications**
- **Attitude stabilization and control**
- **Vehicle Motion Sensing**

DMARS-i Block Diagram



Data

Data Frame Transmission

Time of Validity (TOV) Signal

A 200 Hz TOV (RTI) signal shall be issued. The rising edge of this signal shall be coincident to the time at which the measurements of the gyro and accelerometer data are made. The falling edge shall be coincident to the point at which the data frame transmission is complete.

Data Packet Transmission

A single data packet containing both accelerometer and gyro data shall be transmitted every TOV period (5 msec) once gyro initialization is complete. The complete packet shall be output within 1 to 2 milliseconds (ms) after the rising edge of the TOV signal.

Electrical Interface

The electrical interface is comprised of the TOV signal described above and a serial interface. The interface transmits data only.

The TOV and serial outputs are differential signals. They are compatible with the IEEE standard RS-422 protocol.

The communication parameters are as follows:

Signal Format	RS-422 Differential
Protocol	SDLC
Baud	750 to 1000 kbaud

Communications Settings

The SDLC protocol are defined as follows:

- LSB transmitted first
- Broadcast mode, no address or control data bytes
- IMU is bus station master
- Data transmitted on falling edge of clock
- Data sampled on rising edge of clock
- Frame structure comprised of a 1 byte beginning flag (01111110), followed by the 16 data bytes, followed by a 2 bytes frame check sequence, followed by a 1 byte closing flag (01111110).
- Zero bit insertion used in data bytes and frame check sequence (not in beginning or ending flags)
- Data lines (Rs-422) terminated by external equipment (ie POS computer).

Data Packet Description

The data packet transmitted at 200 Hz contains gyro incremental angular rates, accelerometer incremental velocities, an ID/status byte, and a checksum byte.

The suggested packet is the following 16 Byte message:

Data	Format
Header	Byte = 7E
Counter	Byte, upcount
ID/Status	Byte (see below*)
X gyro Count	High byte
X gyro Count	Low byte
Y gyro Count	High byte
Y gyro Count	Low byte
Z gyro Count	High byte
Z gyro Count	Low byte
ϕ Count	High byte
ϕ Count	Low byte
θ Count	High byte
θ Count	Low byte
ψ Count	High byte
ψ Count	Low byte
Checksum	Byte, exclusive OR, bytes 1-15

Table 3: IMU data packet

Status Byte

The Status byte is implemented as follows

*Status:

7(msb)	/initial bite OK
6	/gyro enabled
5	/temp not too high
4	/temp not too low
3	
2	
1	
0	

Note: Other protocol also available.

Scaling

The LSB scaling on the gyro counts is 0.4 arcsec/pulse. The LSB scaling on the accelerometer counts is 3.38e-5 m/sec/pulse. The maximum range on the gyro data is at least 200 deg/sec. The maximum range on the accelerometer data is at least +/- 6 g.

Accelerometer Data

The accelerometer data is output as incremental velocities in the form of accumulated counts. The incremental velocity data shall be fully compensated for temperature over a range of –20 deg C to +55 deg C. The bandwidth of the accelerometer data shall be at least 100 Hz.

Gyro Data

The gyro data is output as incremental angles in the form of accumulated counts. The incremental angle data is fully compensated for temperature over a range of –20 deg C to +55 deg C. The bandwidth of the data is at least 60 Hz or higher.

Physical Specifications

Power

The IMU operates on +12 and +/-24 Vin DC power (or +/-5 and 15V). The total power consumption (including heaters) is less that 60 Watts.

Connector

The data and power interface to the IMU is via a HDDB26 connector.

Size

The IMU has the following **maximum** dimensions:

4.3" diameter x 4.5" height (less)

Weight

The IMU weights no more than **4 lbs.**

Shock Isolators

The IMU uses shock isolators that meet the following specifications:

Cut-off Frequency: > 100 Hz.

Vibration

The IMU meets the following standard for vibration:

RTCA/DO-160C, section 8

Shock

The IMU meets the following standards for shock:

RTCA/DO-160C, section 7

Operational Shock: 6g /11 ms/ 6 times per direction

Crash Safety: 15g / 11ms/ 1 time per direction

Operating Temperature

The IMU meets the following operational temperature requirement (power-up and output data):

-40 deg C to +60 deg C

Calibrated Temperature

The IMU meets the performance specifications over the following temperature range:

-20 deg C to +55 deg C

Storage Temperature

The IMU meets the following storage temperature:

RTCA/DO-160C, section 4, category A1

-55 deg C to +85 deg C

Humidity

The IMU meets the following humidity specification:

RTCA/DO-160C, section 6, category A

Altitude

The IMU operates at altitudes up to 60000 ft.

Audio Frequency Conducted Susceptibility Power Input	RTCA/DO-160C, section 18, category B	
Induced Signal Susceptibility	RTCA/DO-160C, section 19, category A	
Radio Frequency Susceptibility (radiated and conducted)	RTCA/DO-160C, section 20, category V	
Emission of Radio Frequency Energy	RTCA/DO-160C, section 21, category A	
Lightning Induced Transient Susceptibility	RTCA/DO-160C, section 22,	
CE Conformity: Susceptibility	IEC 801-2 Level 2:	Induced Surge Susceptibility
	IEC 1000-4-3:	Radio Frequency Susceptibility
	IEC 801-4 Level 3:	Induced Burst Susceptibility
CE Conformity: Emission	EN 55022 Class B:	Emission of Radio Frequency radiated
	EN 55022 Class B:	Emission of Radio Frequency conducted

Specification

Size	4.3” dia x 4.5” h (without heatsink)
Volume	100.0 cu. Inch
Weight	5.5 lbs. (without heatsink)
Input Voltage	17 to 40v 3amp peak, nominal 1 amp
Power	22 watts nominal
Roll Axis Gimbal Isolation	22 RPS
Pitch Yaw Axis Strapdown	90 deg/sec
Gyro BW	50 Hz
Gyro Max Rate	90 deg/sec
Shock Isolator	Natural Freq. 90 Hz Damping Ration Coef. 0.12
Random Vibration Spec	$12G_{RMS}$ Random 20 Hz-25 Khz, 3 min.
Sine Vibration Spec	$11.3G_{RMS}$ 450 Hz- 550 Hz, 1 min
Shock	50G, 11msec, Half Sine
Linear Accel	50G , 3 Axis
Operating Temperature	-20 degC to +55 degC
Storage Temperature	-65 degC to +125 degC
Pressure	$2x10^{-5}$ psi
Humidity	100%, No Condensation
Quality Control	MIL-I-45280A MIL-Q-9858A (Chapter 6-4)

DMARS-I Performance

Parameter	Units	DMARS-I-B	DMARS-I-A	DMARS-I-N
Linear				
Bias	Micro-g	200	1,000	1,000
In-run bias stability	Micro-g 1sig or less	10	500	500
Scale factor	Ppm	200	300	300
Axis alignment	Micro-rads	75	300	300
Random noise	Micro-g/sqrt(Hz)	10	30	30
Angular				
Non g-sensitive bias	Deg/hr	0.7	2	5
Bias in-run stability	Deg/hr	<0.3	<0.5	<1.0
Random noise	Deg/sqrt(hr)	0.005	<0.02	<0.02
G sensitivity drift	Deg/hr/g	0.2	0.3	0.3
Scale factor error	Ppm	200	300	300
Axis alignment	Micro-rads	75	300	300

Note:
The IMU meets the following temperature specification **over the temperature range –20 deg C to +55 deg**

Warning

Exporting of any DMARS system out of USA requires Export License issued from U.S. Department of State. Please refer to ITAR (International Traffic in Arms Regulations) or contact ISI before attempting to export of these items.

Maintenance

This unit does not require scheduled maintenance.

MTBF

Estimated MTBF is 10,000 hours.

Trouble shooting and Repair

No user accessible components.
Authorized factory personnel must perform all repairs.
Contact Inertial Science, Inc.

Quality Assurance and Warranty

Quality is an integral part of the design cycle and during fabrication and test of the product at Inertial Science, Inc. In other words, we do not try to "inspect in" the quality, but have it inherent to the design and built. The following are the steps in the Quality Assurance process:

1. During the assembly and integration a traveler accompanies the hardware. This traveler covers all electronics and mechanical assemblies; all wiring; and integration tests. Both the assembler and inspector sign for each step.
2. An extensive Acceptance Test Procedure (depending on cutomers' requirement) is performed prior to shipment. The traveler and ATP data are filed in our system book.
3. A configuration lists and certificate of conformance are supplied with each system.
4. Software verification. The software used for DMARS has been verified by simulation, ISI in-house tests, customer air bearing and vehicle integration tests, and flights in sounding rockets.

Our **warranty** is for one year after the shipment from ISI's facility based on customers' reasonable usage. ISI do intend to resolve any problems occur during this warranty in essential, effective, and timely manner.

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