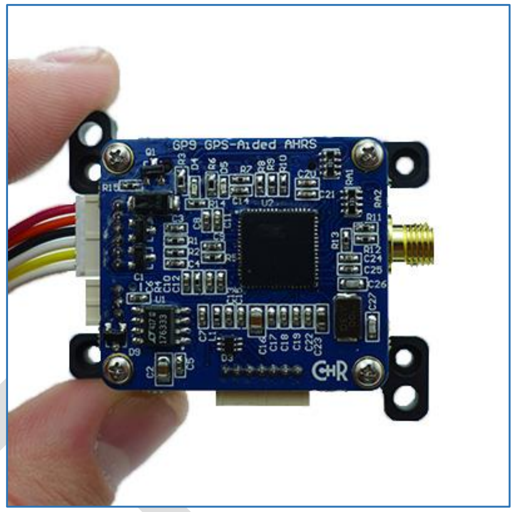
Introduction

The GP9 GPS-Aided AHRS combines MEMS inertial sensors and embedded GPS with an Extended Kalman Filter to produce attitude estimates that are immune to long-term angular drift and sustained acceleration. Unlike attitude sensors that rely on inertial data alone, the GP9 produces reliable attitude estimates even during sustained-G maneuvers like long turns on ground vehicles or aircraft.



The GP9 makes IMU, position/velocity, and attitude/heading data available over a 3.3V UART at user-configurable rates. All data is time-synchronized with the embedded GPS.

Specifications

Attitude and Heading Specifications	
Update Rate	500 Hz
Static Pitch/Roll Accuracy	+/- 2 degrees typical
Dynamic Pitch/Roll Accuracy	+/- 1 degree typical
Static Yaw Accuracy	+/- 5 degrees, with magnetometer
Dynamic Yaw Accuracy	+/- 1 degree typical
Repeatability	0.5 degrees
Resolution	< 0.01 degrees
Data Output Rate	0 Hz to 255 Hz, selectable data
Output Data	Acceleration, angular rates, magnetic field, barometric pressure, pressure-based altitude, GPS altitude, position, velocity, attitude (quaternion, Euler Angles)

Table 1 - GP9 Attitude and Heading Specifications

Gyro Specifications	
Sensitivity change vs. temperature	+/- 2%
Rate noise density	0.03 deg/s/rtHz
Non-linearity	0.2 % FS
Dynamic Range	+/- 2000 deg/s

Table 2 - GP9 Rate Gyro Specifications

GPS Specifications	
Typical Position Accuracy	2.5 meters CEP
Typical Velocity Accuracy	0.1m/s
Timing Accuracy	60ns
Max GPS dynamics	< 4G
Operational Limits	Altitude < 18,000 m, Velocity < 515 m/s
Open Sky TTFF	29 second cold start, 1 second hot start

Table 3 - GP9 GPS Specifications

Other	
Vin	5.0V nominal
Communication	3.3V UART
Baud Rates Supported	9600, 14400, 19200, 38400, 57600, 115200, 128000, 153600, 230400, 256000, 460800, 921600
Power Consumption	< 150mA at 5.0V during GPS seek, < 100mA at 5.0V with GPS lock
Operating Temperature	-20C to +60C
Accelerometer Range	+/- 8 g
Dimensions	1.5” x 1.3” x 0.5”
Weight	0.4 oz (11 grams)

Table 4 - GP9 Misc Specifications

Table of Contents

Revision History

Rev. 1.0 - Initial Release

Rev. 1.1 – Corrected details in Absolute Maximum Ratings section. Added dimensioned drawing, pin description tables, and sections on LED indicators, calibration, and the JTAG header.

Rev. 1.2 – Corrected numbering on CREG_MAG_BIAS registers and DREG registers.

Rev. 1.3 – Corrected missing data registers in Data Registers section.

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Absolute Maximum Ratings

Maximum Mechanical Ratings	
Max Acceleration	3000g for 0.5 ms 10000 g for 0.1ms
Operating Temperature Range	-20C to +60 C
Storage Temperature Range	-40C to +125 C

Maximum Electrical Ratings	
Supply Voltage	-0.3 V to +6.5 V
Minimum Vin	6.1V
Maximum voltage on any input	3.5V

Electrical Characteristics

Electrical Characteristics	
Supply Voltage	4.0V to 6.0V
Supply Current	<150mA during GPS seek <100mA after GPS lock

Mechanical Drawing

Dimensions are in inches

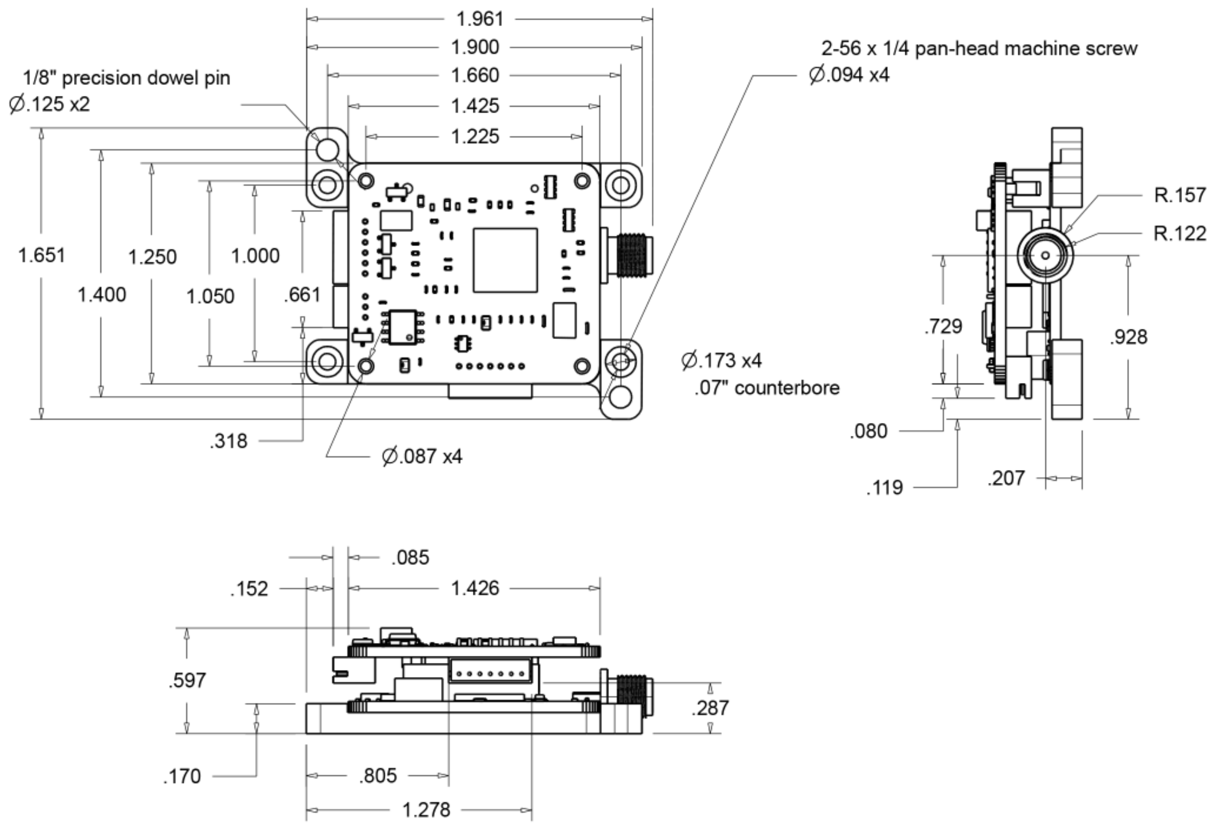
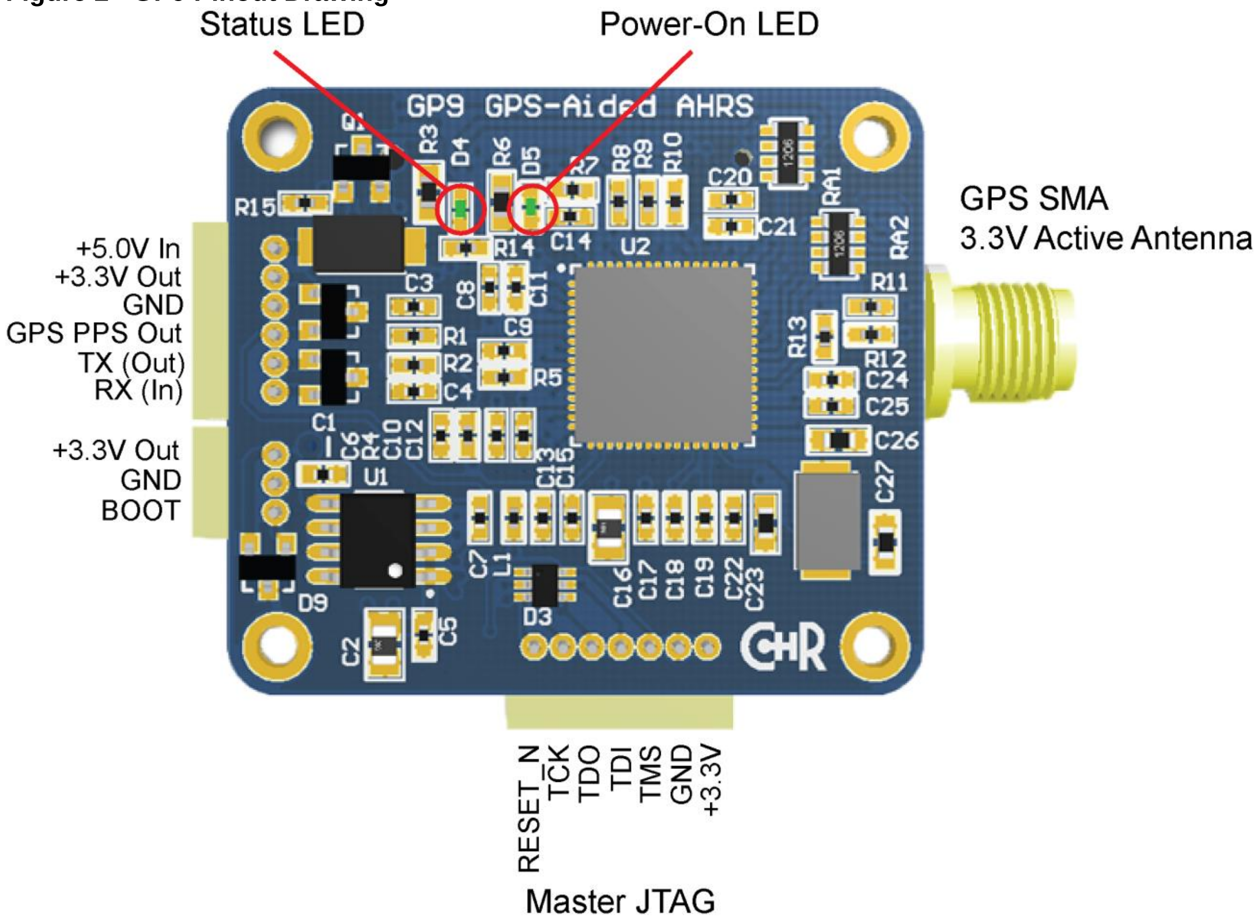


Figure 1 - GP9 Mechanical Drawing

Pinout

Figure 2 - GP9 Pinout Drawing



GP9 6-Pin Main IO Header Pins	
+5.0V In	Main supply input. 5V nominal, 4V to 6V accepted.
+3.3V Out	Regulated 3.3V output, 100mA capacity
GND	Supply ground
GPS PPS Out	GPS PPS output. On GPS lock, pulses high once per second.
TX (Out)	3.3V UART TX output, 115200 baud default
RX (In)	3.3V UART RX input, 115200 baud default

Table 5 - Pinout for GP9 Main IO Header

GP9 3-Pin Peripheral Header	
+3.3V Out	Regulated 3.3V output, 100mA capacity
GND	Supply ground
BOOT	Boot mode select. Float for normal operation. Pull low to start FLASH programming mode for firmware updates.

Table 6 - Pinout for GP9 Peripheral Header

Functional Description

The GP9 is a GPS-Aided Attitude and Heading Reference System (AHRS). Its primary function is to provide a robust attitude solution on dynamic platforms.

The GP9 uses an Extended Kalman Filter to combine data from accelerometers, rate gyros, a magnetometer (optional), barometric pressure, and GPS to produce attitude and heading estimates that are reliable even during aggressive dynamic maneuvers.

Unlike other comparably-priced sensors on the market, the GP9 actually performs *better* on platforms that experience aggressive acceleration and deceleration. The GP9 is also capable of measuring yaw without relying on unpredictable magnetic field measurements.

Attitude Estimates

To avoid issues with gimbal lock, the GP9 attitude estimator uses a quaternion attitude representation. The attitude quaternion represents rotation of the inertial frame to the sensor body frame. The GP9's quaternion attitude is converted internally to Euler Angles as well for applications where Euler Angles are preferred. The Euler Angle attitude is constructed using first yaw rotation, then pitch rotation, and then roll rotation.

The inertial-frame used by the GP9 is a standard right-handed aeronautical inertial frame, with the x-axis pointing north, the y-axis pointing east, and the z-axis pointing down. The sensor body-frame is shown in Figure 3.

The quaternion output of the GP9 is a four-element vector, where the first element (a) is the scalar part, and the last three elements (*b, c,* and *d*) are the vector parts. In keeping with standard aeronautical convention, the quaternion rotation and the equivalent Euler Angle rotation represents rotation of the inertial frame to the body-frame (i.e. the coordinate frame itself is being rotated). This is in contrast to conventions in, for example, computer graphics, where applying a rotation rotates a vector, not the underlying coordinate frame. If you use the quaternion output of the GP9 in a computer graphics application, you may need to conjugate the attitude quaternion to have it behave as expected in your rendering environment.

More details about coordinate frames, quaternions, and Euler Angles are available at www.chrobotics.com/library

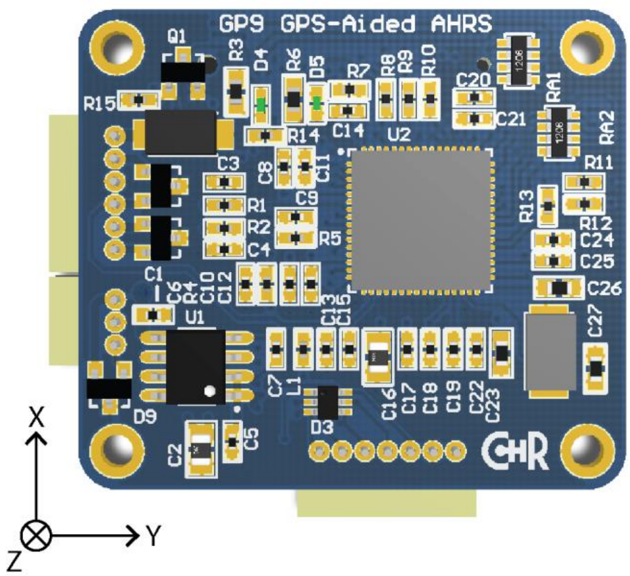


Figure 3 - GP9 Body-Frame Coordinate Axes

Position and Velocity Estimates

The GP9 reads GPS position and velocity at 25 Hz from the onboard GPS. GPS data is used to correct attitude estimates, but position and velocity are *not* computed as states in the filter. Position and velocity are available at the GPS update rate of 25 Hz, but are not smoothed by inertial sensor measurements.

While position and velocity are not states, the GP9 does processes the GPS data to convert it to positions and velocities in meters relative to a configurable home latitude/longitude/altitude. On startup, if GPS home latitude and longitude are not set, then the GP9 will use the first measured latitude and longitude as position zero. All future positions will be referenced to that point. The home location can be set to the current position by issuing a SET_HOME_POSITION command, or any home position can be set by writing to the CREG_HOME_NORTH, CREG_HOME_EAST, and CREG_HOME_UP registers. Once the home position has been set, it can be made permanent by issuing a WRITE_TO_FLASH command.

Raw GPS positions/velocities are available (in degrees lat/lon) in additional to positions and velocities referenced to the GPS home position (in meters and meters/s).

Calibration

The rate gyros and accelerometers on the GP9 are calibrated to compensate for cross-axis alignment, scale factor, and bias errors.

The GP9 is available with two different calibration options, single-point and extended. Single-point calibration is performed near room-temperature and tend to be valid to within +/- 10 degrees (roughly 15 C to 35 C). The closer the temperature remains to the nominal 25C calibration temperature, the better and more consistent the performance. Many cost-sensitive applications can benefit from the lower cost of single-point calibration without sacrificing significant performance.

For best performance, the GP9 can be factory-calibrated over an extended temperature range from 0C to 50C. Temperature-based compensation applies a third-order fit to biases and scale factors just beyond the rated temperature range (the 0C to 50C calibration coefficients are computed from data ranging from -5C to 55C, for example). This ensures that the calibration remains reliable all the way to the extremes of the rated temperatures.

The GP9 comes mounted on CNC-machined mounting brackets. The brackets, with holes for precision alignment dowel pins, can be used to help mount the GP9 in its exact calibration orientation. The brackets can also be removed to save space and weight if needed.

Theory of Operation

The GP9 estimator can be divided into two main components:

1) An INS filter that estimates attitude, heading, and changes in inertial-frame velocity, and
2) An error and bias estimator that compares GPS inertial-frame velocities to INS velocity estimates

Error in the INS velocity estimates are tightly coupled to errors in its attitude estimate. For example, if the yaw angle estimate is off by 90 degrees, actual acceleration in the north direction will "feel" to the INS like acceleration in the east direction. Because INS velocity measurement errors are so closely related to attitude errors, it is possible to use GPS velocity measurements to make attitude corrections.

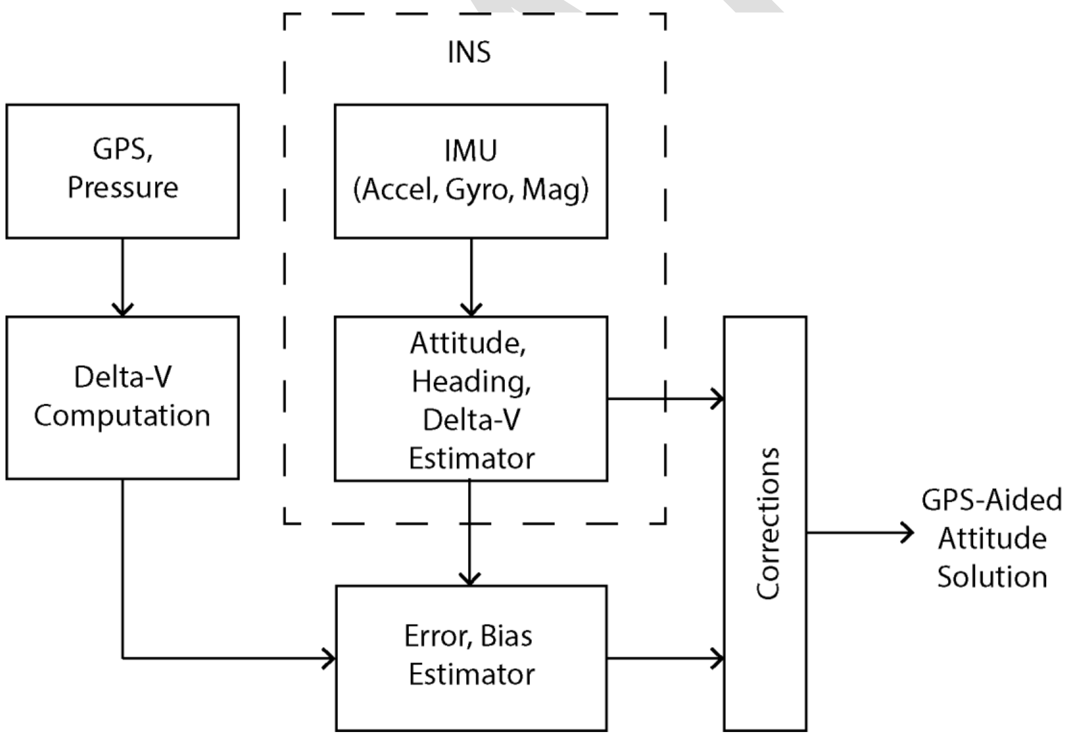


Figure 4 - GP9 Functional Block Diagram

The accelerometers used by the INS measure both physical acceleration and normal forces that prevent the GP9 from accelerating toward the center of the Earth. In order to estimate inertial-frame velocities (the velocities that will be measured by the GPS), the INS uses its attitude estimate to remove normal forces from the accelerometer measurement. Errors in the attitude estimate cause the INS to erroneously misinterpret normal forces as physical acceleration of the sensor. While this may sound like a problem, it actually helps the GP9 correct its attitude estimates even when the sensor isn't accelerating.

The GP9 corrects pitch and roll angle errors at all times, but yaw can only be corrected when the sensor is accelerating. Table 7 summarizes the estimation capabilities of the GP9 given different motion types.

The GP9's onboard bias estimator helps it maintain accurate angle estimates even during long periods of unaccelerated motion.

GP9 Attitude Estimation Capabilities – with and without acceleration		
Motion Type	**Observable states**	**Unobservable States**
Constant Velocity (no acceleration)	- Pitch error - Roll error - X-axis gyro bias - Y-axis gyro bias	- Yaw error - Z-axis gyro bias
Dynamic Velocity (accelerated motion)	- All angles and biases	- None

Table 7 - GP9 Attitude Estimation Capabilities

The implications of the preceding discussion is that the GP9 produces the best estimates when it is accelerating. This is particularly true of the yaw angle estimates. "Acceleration" applies to any change in velocity, which could indicate a change in speed, a change in direction, or both.

So, for example, a car traveling in a straight line on a freeway for a long time might cause the GP9's yaw angle to drift while pitch and roll remain accurate. In contrast, a car driving circles in a roundabout would produce yaw, pitch, and roll estimates that never drift. A platform can be deliberately controlled to change velocity more often so that the yaw estimates remain reliable.

GPS Measurement Updates

Because the GP9 relies on GPS measurements to correct attitude, it is important that the GPS operate in an environment where it can maintain a high-quality lock. If the GPS lock is lost or the quality degrades, the GP9 will stop using it to make attitude corrections.

Significant GPS multipath can negatively affect attitude estimates. For example, driving a car through a narrow urban canyon or under an overpass might cause noticeable yaw angle errors, and (typically) smaller pitch and roll angle errors. Usually, significantly degraded GPS signals are detected and ignored by the GP9 to avoid substantial degradation of the attitude estimates.

The GP9 can be tuned to further reduce the impact of velocity measurements errors. The tradeoff is that the bias estimator can then take longer to converge, and errors in the attitude estimates can take longer to be corrected by the filter. Contact CH Robotics for details about tuning the filter for your specific application.

Magnetometer Measurement Updates

If the GP9 is to be used on a platform that isn't expected to experience consistent dynamic motion, then the magnetometer must be used to prevent the yaw angle estimate from drifting. Magnetometer updates can be enabled on the GP9 by writing to the FILTER_SETTINGS register manually or by using the

CHR Serial Interface to make the configuration change graphically. The CHR Serial Interface can also be used to calibrate the magnetometer to correct soft and hard-iron distortions that would affect the accuracy of the yaw angle estimate.

Whenever possibly, it is best to avoid using the magnetometer. Unpredictable distortions in the Earth's magnetic field can cause arbitrarily large errors in the GP9's yaw angle estimate. Table 8 provides a summary of different platforms and whether the magnetometer would usually be required to maintain consistent yaw angle estimates.

GP9 Magnetometer Requirements for Yaw Estimation	
Platform	**Magnetometer required?**
Car	City driving: No Freeway driving: Probably
Aircraft	RC airplane: No RC rotorcraft: No Small UAV: No Commercial Airliner: Probably
Indoor mobile robot	Yes
Outdoor mobile robot	Slow-moving: Probably Fast (>= 3 m/s): No
Stationary antenna gimbal	Yes
Fast boat/USV	No

Table 8 - Yaw Requirements on Various Platforms

Accelerometer Measurement Updates

If GPS isn't available, the GP9 can be configured to use the accelerometers to make pitch and roll attitude corrections. In this use case, the GP9 becomes sensitive to physical acceleration: dynamic motion causes the attitude estimates to degrade instead of improve. For slow-moving platforms, or indoor operation, the amount of error is minimal. If GPS lock is expected to come and go periodically (say, on a submarine that surfaces and submerges repeatedly), the GP9 can automatically begin using accelerometers when GPS lock is lost, and resume using GPS measurements when lock is reacquired (see the FILTER_SETTINGS register for more details).

When the GP9 is configured to use accelerometers for attitude correction instead of GPS, magnetometer updates must be enabled for the yaw estimate to be reliable.

It is worth noting that when it is not using GPS, the GP9 estimator is effectively equivalent to the estimator on the lower-cost UM7, but with the addition of a gyro bias estimator for improved performance.

Bias Estimator

Even on calibrated rate gyros, imperfect bias repeatability can cause the rate gyros to report erroneous angular rates on the order of tenths of degrees per second. If uncorrected, these bias errors can cause pitch and roll estimate errors on the order of 5 to 10 degrees and, without dynamic motion or magnetometer correction, unbounded errors in the yaw estimate.

The GP9's gyro bias estimator removes these systematic errors in the attitude estimates. On startup, the GP9's bias estimates start at zero and gradually converge to actual rate gyro biases. Before the bias estimator converges, you might observe pitch and roll angles pulled off by 5 to 10 degrees, and then gradually return to their correct values as the bias estimator converges. The intuitive way to think of this behavior is that GPS-based corrections are slowly "pulling" the angle estimates to their correct values, while gyro bias errors pull them away. The magnitude of the angle error depends on how much the rate gyros are trusted by the filter in comparison to the GPS velocity measurements.

This short-term deviation in angle estimates can be avoided by issuing a ZERO_RATE_GYROS command to the GP9 shortly after startup, and while the GP9 is not moving or rotating. The computed gyro trim will bring the estimates close to zero. Issuing a WRITE_TO_FLASH command after zeroing the rate gyros often removes the need to re-zero the gyros when you next cycle power to the GP9.

If the GP9 remains powered, the bias estimator will continually update the gyro bias estimates. As the biases slowly change, the estimator will follow. It is therefore unnecessary to issue additional ZERO_RATE_GYROS commands during normal operation.

If the application makes it impossible to issue a ZERO_RATE_GYROS command to the GP9 on startup, and the temporary angle error is unacceptable, the GP9 can be tuned to minimize the impact of unmeasured gyro biases on startup. The tradeoff is that GPS multipath errors can then have a larger impact on angle estimates. Depending on the specific application, there are also other ways to minimize startup angle errors. Contact CH Robotics for more details about how to tune the filter for your specific application (support@chrobotics.com).

Firmware Upgrades

The GP9 firmware can be upgraded as new releases are published. To upgrade the firmware, the GP9 bootloader must be started in FLASH programming mode. The CHR Serial Interface (available from www.chrobotics.com) can then be used to write the new firmware to the device.

To start the GP9 bootloader in program mode, the BOOT pin on the 3-pin header should be shorted to ground before power is applied. If the bootloader starts in program mode, the status LED will flash three times on startup and then remain solid until the programming process begins.

If programming mode is entered accidentally, simply ensure that the BOOT pin is not shorted to ground and cycle the power.

After programming is complete, disconnect the BOOT pin from ground and cycle power to begin.

Status Indicator LEDs

The GP9 is fitted with two indicator LEDs to show its status (see Figure 2 for locations of the indicators).

The "power-on" LED turns on whenever the device is powered.

During normal operation, the "status" LED will turn on and remain on continuously while the internal GPS acquires a lock. Once the GPS is locked, the LED will toggle once every second.

If the BOOT pin is pulled low before applying power, the GP9 bootloader will start in FLASH programming mode and the status LED will flash three times before turning solid. Once FLASH programming begins, the status LED will turn off.

Master JTAG Header

The JTAG header is used in-factory to program the bootloader and isn't used during normal operation.

Serial Communication

The GP9 UART operates at a 3.3V logic level with 8 data bits, 1 stop bit, and no parity.

The TTL UART output of the GP9 is NOT compatible with the RS-232 serial port commonly found on desktop computers. To interface the GP9 with a computer, it is necessary to utilize a voltage translator or USB-TLL converter to prevent damage to the device. We recommend using our USB Expansion Board for easily connecting the GP9 to a computer.

By default, the serial baud rate of the GP9 is set at 115200, but the baud rate can be changed by the end user if desired.

All data and settings on the GP9 are accessible via a set of addressed registers. Configuration registers store settings that control the operation of the GP9. Data registers make sensor data and estimator outputs available. Command registers instruct the GP9 to execute various commands. With the exception of command registers, any register can be read or modified over the UART using a binary serial communication protocol.

Binary Packet Structure

Data transmitted and received by the GP9 is formatted into packets containing:

1. The three character start sequence 's', 'n', 'p' to indicate the start of a new packet (i.e. **s**tart **n**ew **p**acket)
2. A "packet type" (PT) byte describing the function and length of the packet
3. An address byte indicating the address of the register or command
4. A sequence of data bytes, the length of which is specified in the PT byte
5. A two-byte checksum for error-detection

Table 9 - UART Serial Packet Structure

's'	'n'	'p'	packet type (PT)	Address	Data Bytes (D0...DN-1)	Checksum 1	Checksum 0

All packets sent and received by the GP9 must conform to the format given in Table 9.

The PT byte specifies whether the packet is a read or a write operation, whether it is a batch operation, and the length of the batch operation (when applicable). The PT byte is also used by the GP9 to respond to commands. The specific meaning of each bit in the PT byte is given in Table 10.

Table 10 - Packet Type (PT) byte

7	6	5	4	3	2	1	1
Has Data	Is Batch	BL3	BL2	BL1	BL0	Hidden	CF

Table 11 - Packet Type (PT) Bit Descriptions

Bit(s)	Description
7	Has Data: If the packet contains data, this bit is set (1). If not, this bit is cleared (0).
6	Is Batch: If the packet is a batch operation, this bit is set (1). If not, this bit is cleared (0)
5:2	Batch Length (BL): Four bits specifying the length of the batch operation. Unused if bit 7 is cleared. The maximum batch length is 2^4 = 16 registers
1	Hidden: If set, then the packet address specified in the "Address" field is a "hidden" address. Hidden registers are used to store factory calibration and filter tuning coefficients that do not typically need to be viewed or modified by the user. This bit should always be set to 0 to avoid altering factory configuration.
0	Command Failed (CF): Used by the GP9 to report when a command has failed. Must be set to zero for all packets written to the GP9.

The address byte specifies which register will be involved in the operation. During a read operation (Has Data = 0), the address specifies which register to read. During a write operation (Has Data = 1), the address specifies where to place the data contained in the data section of the packet. For a batch read/write operation, the address byte specifies the starting address of the operation.

The "Data Bytes" section of the packet contains data to be written to one or more registers. There is no byte in the packet that explicitly states how many bytes are in this section because it is possible to determine the number of data bytes that should be in the packet by evaluating the PT byte.

If the Has Data bit in the PT byte is cleared (Has Data = 0), then there are no data bytes in the packet and the Checksum immediately follows the address. If, on the other hand, the Has Data bit is set (Has Data = 1) then the number of bytes in the data section depends on the value of the Is Batch and Batch Length portions of the PT byte.

For a batch operation (Is Batch = 1), the length of the packet data section is equal to 4*(Batch Length). Note that the batch length refers to the number of registers in the batch, NOT the number of bytes. Registers are 4 bytes long.

For a non-batch operation (Is Batch = 0), the length of the data section is equal to 4 bytes (one register). The data section lengths and total packet lengths for different PT configurations are shown below.

Table 12 - Packet Length Summary

Has Data	Is Batch	Data Section Length (bytes)	Total Packet Length (bytes)
0	NA	0	7
1	0	4	11
1	1	4*(Batch Length)	7 + 4*(Batch Length)

Note that if a packet is a batch operation, the batch length must be greater than zero.

The two checksum bytes consist of the unsigned 16-bit sum of all preceding bytes in the packet, including the packet header. A batch packet with batch length = 1 is equivalent to a non-batch packet.

Read Operations

To initiate a serial read of one or more registers aboard the sensor, a packet should be sent with the "Has Data" bit cleared. This tells the device that this will be a read operation from the address specified in the packet's "Address" byte. If the "Is Batch" bit is set, then the packet will trigger a batch read in which the "Address" byte specifies the address of the first register to be read.

In response to a read packet, the GP9 will send a packet in which the "Has Data" bit is set, and the "Is Batch" and "Batch Length" bits are equivalent to those of the packet that triggered the read operation. The register data will be contained in the "Data Bytes" section of the packet.

Write Operations

To initiate a serial write into one or more registers aboard the sensor, a packet should be sent to the GP9 with the "Has Data" bit set. This tells the device that the incoming packet contains data that should be written to the register specified by the packet's "Address" byte. If a batch write operation is to be performed, the "Is Batch" bit should be set, and the "Batch Length" bits should indicate the number of registers that are to be written to.

In response to a write packet, the GP9 will update the contents of the specified register(s) with the contents of the data section of the packet. It will then transmit a COMMAND_COMPLETE packet to indicate that the write operation succeeded. A COMMAND_COMPLETE packet is a packet with PT = 0 (no data, no batch) and with an address matching the address of the register to which the write operation was made, or the start address of the write operation if this was a batch write.

Note that the COMMAND_COMPLETE packet is equivalent to a packet that would cause the GP9 to initiate a read operation on the address to which data was just written. Since the packet is going from the sensor to the host, however, its meaning is different (it would not make sense for the GP9 to request the contents of one of its registers from an external host).

Command Operations

There are a variety of register address that do not correspond with actual physical registers aboard the GP9. These "command" addresses are used to cause the sensor to execute specific commands (there are commands for executing calibration operations, resetting the onboard filters, etc. See the Register Overview in this document for more details).

To initiate a command, simply send a packet to the GP9 with the command's address in the packet "Address" byte. The PT byte should be set to zero for a command operation.

If the GP9 successfully completes the specified command, then a COMMAND_COMPLETE packet is returned with the command address in the "Address" byte of the response packet. If the command fails, the device responds by sending a COMMAND_FAILED packet. The COMMAND_FAILED packet is equivalent to the COMMAND_COMPLETE packet except that the "Command Failed" bit in the PT byte is set (CF = 1).

In some cases, a command will cause specific packets to be sent other than the COMMAND_COMPLETE packet. A GET_FW_VERSION command will, for example, return a packet containing the version of the firmware installed on the GP9. In this and similar cases, the COMMAND_COMPLETE packet is not sent.

Register Overview

There are three types of registers onboard the GP9: configuration registers, data registers, and command registers.

Configuration registers begin at address 0x00 and are used to configure GP9's filter settings and communication behavior. Configuration register contents can be written to onboard flash to allow settings to be maintained when the device is powered down.

Data registers begin at address 0x55 (85), and store raw and processed data from the sensors along with estimated states. Unlike configuration registers, data register contents cannot be written to flash.

Command registers technically aren't registers at all, but they provide a convenient way to send commands to the GP9 when those commands do not require additional data beyond the command itself. For example, a command to run an onboard gyro bias calibration routine is triggered by querying the ZERO_GYROS command register. By using a unique register address for each command, the same communication architecture used to read from and write to data and configuration registers can be used to send commands to the GP9. Command registers begin at address 0xAA.

Configuration Registers

Address HEX (dec)	Register Name	Register Description
0x00 (0)	CREG_COM_SETTINGS	General communication settings
0x01 (1)	CREG_COM_RATES1	Broadcast rate settings
0x02 (2)	CREG_COM_RATES2	Broadcast rate settings
0x03 (3)	CREG_COM_RATES3	Broadcast rate settings
0x04 (4)	CREG_COM_RATES4	Broadcast rate settings
0x05 (5)	CREG_COM_RATES5	Broadcast rate settings
0x06 (6)	CREG_COM_RATES6	Broadcast rate settings
0x07 (7)	CREG_COM_RATES7	Broadcast rate settings
0x08 (8)	CREG_FILTER_SETTINGS	Misc. filter settings
0x09 (9)	CREG_HOME_NORTH	GPS north position to consider position 0
0x0A (10)	CREG_HOME_EAST	GPS east position to consider position 0
0x0B (11)	CREG_HOME_UP	GPS altitude to consider position 0
0x0C (12)	CREG_ZERO_PRESSURE	Pressure at altitude 0
0x0D (13)	RESERVED	This register address is reserved for future use
0x0E (14)	CREG_GYRO_TRIM_X	Bias trim for x-axis rate gyro
0x0F (15)	CREG_GYRO_TRIM_Y	Bias trim for y-axis rate gyro
0x10 (16)	CREG_GYRO_TRIM_Z	Bias trim for z-axis rate gyro
0x11 – 0x41 (17 – 65)	RESERVED	These registers are reserved for future use
0x42 (66)	CREG_MAG_CAL1_1	Row 1, Column 1 of magnetometer calibration matrix
0x43 (67)	CREG_MAG_CAL1_2	Row 1, Column 2 of magnetometer calibration matrix
0x44 (68)	CREG_MAG_CAL1_3	Row 1, Column 3 of magnetometer calibration matrix
0x45 (69)	CREG_MAG_CAL2_1	Row 2, Column 1 of magnetometer calibration matrix
0x46 (70)	CREG_MAG_CAL2_2	Row 2, Column 2 of magnetometer calibration matrix
0x47 (71)	CREG_MAG_CAL2_3	Row 2, Column 3 of magnetometer calibration matrix
0x48 (72)	CREG_MAG_CAL3_1	Row 3, Column 1 of magnetometer calibration matrix
0x49 (73)	CREG_MAG_CAL3_2	Row 3, Column 2 of magnetometer calibration matrix
0x4A (74)	CREG_MAG_CAL3_3	Row 3, Column 3 of magnetometer calibration matrix
0x4B (75)	CREG_MAG_BIAS_X	Magnetometer X-axis bias
0x4C (76)	CREG_MAG_BIAS_Y	Magnetometer Y-axis bias
0x4D (77)	CREG_MAG_BIAS_Z	Magnetometer Z-axis bias

Table 13 - List of GP9 Configuration Registers

Data Registers

Address	Register Name	Register Description
0x55 (85)	DREG_HEALTH	Contains information about the health and status of the GP9
0x56 (86)	DREG_GYRO_RAW_XY	Raw X and Y rate gyro data
0x57 (87)	DREG_GYRO_RAW_Z	Raw Z rate gyro data
0x58 (88)	DREG_GYRO_TIME	Time at which rate gyro data was acquired
0x59 (89)	DREG_ACCEL_RAW_XY	Raw X and Y accelerometer data
0x5A (90)	DREG_ACCEL_RAW_Z	Raw Z accelerometer data
0x5B (91)	DREG_ACCEL_TIME	Time at which accelerometer data was acquired
0x5C (92)	DREG_MAG_RAW_XY	Raw X and Y magnetometer data
0x5D (93)	DREG_MAG_RAW_Z	Raw Z magnetometer data
0x5E (94)	DREG_MAG_RAW_TIME	Time at which magnetometer data was acquired
0x5F (95)	DREG_PRESSURE_RAW	Raw absolute pressure data
0x60 (96)	DREG_PRESSURE_TIME	Time at which absolute pressure data was acquired
0x61 (97)	DREG_TEMPERATURE_RAW1	Raw temperature data register
0x62 (98)	DREG_TEMPERATURE_RAW2	Raw temperature data register
0x63 (99)	DREG_TEMPERATURE_TIME	Time at which temperature data was acquired
0x64 (100)	DREG_GYRO_PROC_X	Processed x-axis rate gyro data
0x65 (101)	DREG_GYRO_PROC_Y	Processed y-axis rate gyro data
0x66 (102)	DREG_GYRO_PROC_Z	Processed z-axis rate gyro data
0x67 (103)	DREG_GYRO_PROC_TIME	Time at which rate gyro data was acquired
0x68 (104)	DREG_ACCEL_PROC_X	Processed x-axis accel data
0x69 (105)	DREG_ACCEL_PROC_Y	Processed y-axis accel data
0x6A (106)	DREG_ACCEL_PROC_Z	Processed z-axis accel data
0x6B (107)	DREG_ACCEL_PROC_TIME	Time at which accelerometer data was acquired
0x6C (108)	DREG_MAG_PROC_X	Processed x-axis magnetometer data
0x6D (109)	DREG_MAG_PROC_Y	Processed y-axis magnetometer data
0x6E (110)	DREG_MAG_PROC_Z	Processed z-axis magnetometer data
0x6F (111)	DREG_MAG_PROC_TIME	Time at which magnetometer data was acquired
0x70 (112)	DREG_PRESSURE_PROC	Processed absolute pressure data
0x71 (113)	DREG_PRESSURE_PROC_TIME	Time at which absolute pressure data was acquired
0x72 (114)	DREG_TEMPERATURE_PROC1	Processed temperature data
0x73 (115)	DREG_TEMPERATURE_PROC2	Processed temperature data
0x74 (116)	DREG_TEMPERATURE_PROC_TIME	Time at which temperature data was acquired
0x75 (117)	DREG_QUAT_AB	Quaternion elements A and B
0x76 (118)	DREG_QUAT_CD	Quaternion elements C and D

0x77 (119)	DREG_QUAT_TIME	Time at which the sensor was at the specified quaternion rotation
0x78 (120)	DREG_EULER_PHI_THETA	Roll and pitch angles
0x79 (121)	DREG_EULER_PSI	Yaw angle
0x7A (122)	DREG_EULER_TIME	Time of computed Euler attitude
0x7B (123)	DREG_POSITION_NORTH	North position in meters
0x7C (124)	DREG_POSITION_EAST	East position in meters
0x7D (125)	DREG_POSITION_UP	Altitude in meters
0x7E (126)	DREG_POSITION_TIME	Time of estimated position
0x7F (127)	DREG_VELOCITY_NORTH	North velocity
0x80 (128)	DREG_VELOCITY_EAST	East velocity
0x81 (129)	DREG_VELOCITY_UP	Altitude velocity
0x82 (130)	RESERVED	This register is reserved for future use
0x83 (131)	DREG_VELOCITY_TIME	Time of velocity estimate
0x84 (132)	DREG_GPS_LATITUDE	GPS latitude
0x85 (133)	DREG_GPS_LONGITUDE	GPS longitude
0x86 (134)	DREG_GPS_ALTITUDE	GPS altitude
0x87 (135)	DREG_GPS_COURSE	GPS course
0x88 (136)	DREG_GPS_SPEED	GPS speed
0x89 (137)	DREG_GPS_TIME	GPS time
0x8A (138)	DREG_GPS_DATE	GPS date register
0x8B (139)	DREG_GPS_SAT_1_2	GPS satellite information
0x8C (140)	DREG_GPS_SAT_3_4	GPS satellite information
0x8D (141)	DREG_GPS_SAT_5_6	GPS satellite information
0x8E (142)	DREG_GPS_SAT_7_8	GPS satellite information
0x8F (143)	DREG_GPS_SAT_9_10	GPS satellite information
0x90 (144)	DREG_GPS_SAT_11_12	GPS satellite information
0x91 (145)	DREG_GYRO_BIAS_X	X-axis gyro bias estimate
0x92 (146)	DREG_GYRO_BIAS_Y	Y-axis gyro bias estimate
0x93 (147)	DREG_GYRO_BIAS_Z	Z-axis gyro bias estimate
0x94 (148)	DREG_BIAS_X_VARIANCE	Variance of gyro x-axis bias estimate
0x95 (149)	DREG_BIAS_Y_VARIANCE	Variance of gyro y-axis bias estimate
0x96 (150)	DREG_BIAS_Z_VARIANCE	Variance of gyro z-axis bias estimate
0x97 (151)	DREG_QUAT_A_VARIANCE	Variance of quaternion element *a*
0x98 (152)	DREG_QUAT_B_VARIANCE	Variance of quaternion element *b*
0x99 (153)	DREG_QUAT_C_VARIANCE	Variance of quaternion element *c*
0x9A (154)	DREG_QUAT_D_VARIANCE	Variance of quaternion element *d*

Table 14 - List of GP9 Data Registers

Commands

Address	Name	Description
0xAA (170)	GET_FW_REVISION	Causes the GP9 to respond with a packet containing the current firmware revision.
0xAB (171)	FLASH_COMMIT	Writes all current configuration settings to flash
0xAC (172)	RESET_TO_FACTORY	Reset all settings to factory defaults
0xAD (173)	ZERO_GYROS	Causes the rate gyro biases to be calibrated.
0xAE (174)	SET_HOME_POSITION	Sets the current GPS location as position (0,0)
0xAF (175)	RESERVED	RESERVED
0xB0 (176)	RESERVED	RESERVED
0xB1 (177)	RESERVED	RESERVED
0xB2 (178)	RESERVED	RESERVED
0xB3 (179)	RESET_EKF	Resets the EKF

Table 15 - List of GP9 Commands

Configuration Registers

A set of 32-bit configuration registers allows the GP9's behavior to be customized for specific applications. In general, settings are most easily configured using the CHR Serial Interface, which allows the contents of each configuration register to be set without understanding the register contents at the bit/byte level.

This section outlines in detail the contents and functionality of each register.

CREG_COM_SETTINGS – 0x00 (0)

Summary

The CREG_COM_SETTINGS register is used to set the GP9's serial port baud rate and to enable or disable the automatic transmission of sensor data and estimated states (telemetry).

Register Contents

B3								B2							
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
BAUD_RATE				*Reserved*											

B1								B0							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved							GPS	Reserved			SAT	Reserved			

Description

Bits	Name	Description
31:28	BAUD_RATE	Sets the baud rate of the GP9 serial port. *0 = 9600* *1 = 14400* *2 = 19200* *3 = 38400* *4 = 57600* *5 = 115200* *6 = 128000** *7 = 153600** *8 = 230400** *9 = 256000** *10 = 460800** *11 = 921600** *12:15 = reserved* ** Most PC serial ports do not support baud-rates above 115200*
27:9	Reserved	These bits are reserved for future use
8	GPS	If set, this bit causes GPS data to be transmitted automatically whenever new GPS data is received. GPS data is stored in registers 131 to 136. These registers will be transmitted in a batch packet starting at address 131.
7:5	Reserved	These bits are reserved for future use
4	SAT	If set, this bit causes satellite details to be transmitted whenever they are provided by the GPS. Satellite information is stored in registers 137 to 142. These registers will be transmitted in a batch packet beginning at address 137.
3:0	Reserved	These bits are reserved for future use

CREG_COM_RATES1 – 0x01 (1)

Summary

The CREG_COM_RATES1 register sets desired telemetry transmission rates in Hz for raw accelerometer, gyro, magnetometer, and pressure data. If the specified rate is 0, then no data is transmitted.

Register Contents

B3	B2	B1	B0
RAW_ACCEL_RATE	RAW_GYRO_RATE	RAW_MAG_RATE	RAW_PRESSURE_RATE

Description

Bits	Name	Description
31:24	RAW_ACCEL_RATE	Specifies the desired raw accelerometer data broadcast rate in Hz. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
23:16	RAW_GYRO_RATE	Specifies the desired raw gyro data broadcast rate in Hz. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
15:8	RAW_MAG_RATE	Specifies the desired raw magnetometer data broadcast rate in Hz. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
7:0	RAW_PRESSURE_RATE	Specifies the desired raw pressure data broadcast rate in Hz. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.

Raw accelerometer data is stored in registers 89 to 91. When the raw accel rate is greater than 0, the accelerometer data is transmitted in a batch packet of length 3 with start address 89.

Raw rate gyro data is stored in registers 86 to 88. When the raw gyro rate is greater than 0, the rate gyro data is transmitted in a batch packet of length 3 with start address 86.

Raw magnetometer data is stored in registers 92 to 94. When the raw magnetometer rate is greater than 0, the magnetometer data is transmitted in a batch packet of length 3 with start address 92.

Raw pressure data is stored in registers 95 to 96. When the raw pressure rate is greater than 0, the pressure data is transmitted in a batch packet of length 2 with start address 95.

If the "all raw data rate" in CREG_COM_RATES2 is greater than 0, then all gyro, accelerometer, magnetometer, and pressure data will be transmitted together. The rates in CREG_COM_RATES1 are then not used.

CREG_COM_RATES2 – 0x02 (2)

Summary

The CREG_COM_RATES2 register sets desired telemetry transmission rates for all raw data and temperature. If the specified rate is 0, then no data is transmitted.

Register Contents

B3	B2	B1	B0
RAW_TEMP_RATE	RES	RES	ALL_RAW_RATE

Description

Bits	Name	Description
31:24	RAW_TEMP_RATE	Specifies the desired broadcast rate for raw temperature data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
23:16	RES	These bits are reserved for future use
15:8	RES	These bits are reserved for future use
7:0	ALL_RAW_RATE	Specifies the desired broadcast rate for all raw sensor data. If set, this overrides the broadcast rate setting for individual raw data broadcast rates. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.

Raw sensor data occupies registers 86 through 99. If the raw data broadcast rate is greater than 0, then all raw data is sent in one batch packet of length 14, with start address 86.

Raw temperature data is stored in registers 97 through 99. If the raw temperature broadcast rate is greater than 0, then raw temperature data will be sent in a batch packet of length 3 with start address 97. If all raw data is being transmitted (as specified by byte 3 of this register), then the temperature data will be transmitted as part of the raw batch packet at “all raw rate” instead of the raw temperature rate.

CREG_COM_RATES3 – 0x03 (3)

Summary

The CREG_COM_RATES3 register sets desired telemetry transmission rates for processed sensor data. If the specified rate is 0, then no data is transmitted.

Register Contents

B3	B2	B1	B0
PROC_ACCEL_RATE	PROC_GYRO_RATE	PROC_MAG_RATE	PROC_PRESS_RATE

Description

Bits	Name	Description
31:24	PROC_ACCEL_RATE	Specifies the desired broadcast rate for processed accelerometer data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
23:16	PROC_GYRO_RATE	Specifies the desired broadcast rate for processed rate gyro data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
15:8	PROC_MAG_RATE	Specifies the desired broadcast rate for processed magnetometer data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
7:0	PROC_PRESS_RATE	Specifies the desired broadcast rate for processed pressure data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.

Processed accelerometer data is stored in registers 104 to 107. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 4 and start address 104.

Processed rate gyro data is stored in registers 100 to 103. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 4 and start address 100.

Processed magnetometer data is stored in registers 108 to 111. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 4 and start address 108.

Processed accelerometer data is stored in registers 112 to 113. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 2 and start address 112.

If the “all processed data broadcast rate” setting in register CREG_COM_RATES4 is not zero, then the rates specified in the CREG_COM_RATES3 register are overridden.

CREG_COM_RATES4 – 0x04 (4)

Summary

The CREG_COM_RATES4 register sets desired telemetry transmission rates for all processed data and temperature. If the specified rate is 0, then no data is transmitted.

Register Contents

B3	B2	B1	B0
PROC_TEMP_RATE	RES	RES	ALL_PROC_RATE

Description

Bits	Name	Description
31:24	PROC_TEMP_RATE	Specifies the desired broadcast rate for processed temperature data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
23:16	RES	These bits are reserved for future use
15:8	RES	These bits are reserved for future use
7:0	ALL_PROC_RATE	Specifies the desired broadcast rate for raw all processed data. If set, this overrides the broadcast rate setting for individual processed data broadcast rates. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.

Processed temperature is stored in registers 114 to 116. If the rate setting is greater than 0, then processed temperature data is transmitted in a batch packet with length 3 and start address 114.

All processed data comprises registers 100 through 116 (a total of 17 registers). Because 17 registers is greater than the maximum batch length, all processed data is sent in TWO packets instead of one. If the rate settings is greater than 0, then the first packet is a batch with length 8 and start address 114. The second packet is a batch with length 9 and start address 108.

CREG_COM_RATES5 – 0x05 (5)

Summary

The CREG_COM_RATES5 register sets desired telemetry transmission rates for quaternions, Euler Angles, position, and velocity estimates. If the specified rate is 0, then no data is transmitted.

Register Contents

B3	B2	B1	B0
QUAT_RATE	EULER_RATE	POSITION_RATE	VELOCITY_RATE

Description

Bits	Name	Description
31:24	QUAT_RATE	Specifies the desired broadcast rate for quaternion data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
23:16	EULER_RATE	Specifies the desired broadcast rate for Euler Angle data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
15:8	POSITION_RATE	Specifies the desired broadcast rate position. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
7:0	VELOCITY_RATE	Specifies the desired broadcast rate for velocity. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.

Quaternion data is stored in registers 117 to 119. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet with length 3 and start address 117.

Euler Angle data is stored in registers 120 to 122. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 3 and start address 120.

Position data is stored in registers 123 to 126. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 4 and start address 123.

Velocity data is stored in registers 127 to 130. If the specified broadcast rate is greater than 0, then the data will be transmitted in a batch packet of length 4 and start address 127.

If the "pose broadcast rate" setting in register CREG_COM_RATES6 is not zero, then the rates specified by EULER_RATE and POSITION_RATE are overridden.

CREG_COM_RATES6 – 0x06 (6)

Summary

The CREG_COM_RATES6 register sets desired telemetry transmission rates for pose (Euler/position packet) and health. If the specified rate is 0, then no data is transmitted.

Register Contents

B3								B2							
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
POSE_RATE								RESERVED				HEALTH_RATE			

B1								B0							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VARIANCE_RATE								GYRO_BIAS_RATE							

Description

Bits	Name	Description
31:24	POSE_RATE	Specifies the desired broadcast rate for pose (Euler Angle and position) data. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
23:20	RESERVED	These bits are reserved for future use.
19:16	HEALTH_RATE	Specifies the desired broadcast rate for the sensor health packet. *0 = off* *1 = 0.125 Hz* *2 = 0.25 Hz* *3 = 0.5 Hz* *4 = 1 Hz* *5 = 2 Hz* *6 = 4 Hz* *7:15 = Unused** ** Will default to 1Hz*
15:8	VARIANCE_RATE	Specifies the desired broadcast rate for state variances. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.
7:0	GYRO_BIAS_RATE	Specifies the desired broadcast rate for estimated gyro biases. The data is stored as an unsigned 8-bit integer, yielding a maximum rate of 255 Hz.

Pose data (Euler Angles and position) is stored in registers 120 to 126. If the pose rate is greater than 0, then pose data will be transmitted in a batch packet with length 7 and start address 120.

Health data is stored in register address 85. If the health rate is not 0, then health data will be transmitted as a non-batch packet with address 85.

Variance data is stored in registers 148 to 154. If the variance transmission rate is greater than 0, then variance data will be transmitted in a batch packet with length 7 and start address 148.

Gyro bias data is stored in registers 145 to 147. If the bias transmission rate is greater than 0, then estimated gyro biases will be transmitted in a batch packet with length 3 and start address 145.

CREG_COM_RATES7 – 0X07 (7)

Summary

The CREG_COM_RATES7 register sets desired transmission rates for CHR NMEA-style packets.

Register Contents

B3								B2							
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
HEALTH_RATE				POSE_RATE				ATTITUDE_RATE				SENSOR_RATE			

B1								B0							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RESERVED															

Description

Bits	Name	Description
31:28	HEALTH_RATE	Specifies the desired broadcast rate for CHR NMEA-style health packet. *0 = off* *1 = 0.125 Hz* *2 = 0.25 Hz* *3 = 0.5 Hz* *4 = 1 Hz* *5 = 2 Hz* *6 = 4 Hz* *7 = 8 Hz* *8:15 = Unused** ** Will default to 1Hz*
27:24	POSE_RATE	Specifies the desired broadcast rate for CHR NMEA-style pose (Euler Angle/position) packet. *0 = off* *1 = 0.125 Hz* *2 = 0.25 Hz* *3 = 0.5 Hz* *4 = 1 Hz* *5 = 2 Hz* *6 = 4 Hz* *7 = 8 Hz* *8:15 = Unused**

		** Will default to 1Hz*
23:20	ATTITUDE_RATE	Specifies the desired broadcast rate for CHR NMEA-style attitude packet. *0 = off* *1 = 0.125 Hz* *2 = 0.25 Hz* *3 = 0.5 Hz* *4 = 1 Hz* *5 = 2 Hz* *6 = 4 Hz* *7 = 8 Hz* *8:15 = Unused** ** Will default to 1Hz*
19:16	SENSOR_RATE	Specifies the desired broadcast rate for CHR NMEA-style sensor data packet *0 = off* *1 = 0.125 Hz* *2 = 0.25 Hz* *3 = 0.5 Hz* *4 = 1 Hz* *5 = 2 Hz* *6 = 4 Hz* *7 = 8 Hz* *8:15 = Unused** ** Will default to 1Hz*
15:0	RESERVED	These bits are reserved for future use.

CREG_FILTER_SETTINGS – 0x08 (8)

Summary

This register contains settings used to configure high-level behavior of the filter.

Register Contents

B3								B2							
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RES	GPS	MAG	ACC	RESERVED											

B1								B0							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RESERVED															

Description

Bits	Name	Description
31	RESERVED	This bit is reserved for future use
30	GPS	If set, GPS will be used to update attitude estimates Default = 1
29	MAG	If set, the magnetometer will be used to update attitude estimates. Default = 0
28	ACC	If set, the accelerometer will be used to update attitude estimates whenever GPS lock isn't available. Default = 1
27:0	RESERVED	These bits are reserved for future use

CREG_HOME_NORTH – 0x09 (9)

Summary

This register sets the north home latitude in degrees, used to convert GPS coordinates to position in meters from home.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_HOME_EAST – 0x0A (10)

Summary

This register sets the east home longitude in degrees, used to convert GPS coordinates to position in meters from home.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_HOME_UP – 0x0B (11)

Summary

This register sets the home altitude in meters. Used to convert GPS coordinates to position in meters from home.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_ZERO_PRESSURE – 0x0C (12)

Summary

This register sets the expected barometric pressure reading at zero altitude. Used to compensate for varying pressure with weather.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

RESERVED – 0x0D (13)

Summary

This register is reserved for future use.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_GYRO_TRIM_X – 0x0E (14)

Summary

This register sets the x-axis rate gyro trim, which is used to add additional bias compensation for the rate gyros during calls to the ZERO_GYRO_BIAS command.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_GYRO_TRIM_Y – 0x0F (15)

Summary

This register sets the y-axis rate gyro trim, which is used to add additional bias compensation for the rate gyros during calls to the ZERO_GYRO_BIAS command.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_GYRO_TRIM_Z – 0x10 (16)

Summary

This register sets the z-axis rate gyro trim, which is used to add additional bias compensation for the rate gyros during calls to the ZERO_GYRO_BIAS command.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

RESERVED – 0x11 – 0x41 (17 – 65)

These registers are reserved for future use.

CREG_MAG_CAL1_1 to CREG_MAG_CAL3_3 – 0x42 (66) to 0x4A (74)

Summary

These registers store the 9 entries into a 3x3 matrix that is used to perform soft-iron calibration of the magnetometer on the device. These terms can be computed by performing magnetometer calibration with the CHR Serial Interface. Terms are stored in row-major order.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_MAG_BIAS_X – 0x4B (75)

Summary

This registers stores a bias term for the magnetometer x-axis for hard-iron calibration. This term can be computed by performing magnetometer calibration with the CHR Serial Interface.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_MAG_BIAS_Y – 0x4C (76)

Summary

This registers stores a bias term for the magnetometer y-axis for hard-iron calibration. This term can be computed by performing magnetometer calibration with the CHR Serial Interface.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

CREG_MAG_BIAS_Z – 0x4D (77)

Summary

This registers stores a bias term for the magnetometer z-axis for hard-iron calibration. This term can be computed by performing magnetometer calibration with the CHR Serial Interface.

Register Contents

B3	B2	B1	B0
32-bit IEEE Floating Point Value			

Data Registers

DREG_HEALTH – 0x55 (85)

Summary

The health register reports the current status of the GPS module and the other sensors on the GP9. Monitoring the health register is the easiest way to monitor the quality of the GPS lock and to watch for other problems that could affect the behavior of the GP9.

Register Contents

B3								B2							
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SATS_USED						HDOP									

B1								B0							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SATS_IN_VIEW						OVF	RES		GPS_ST		PRESS	ACCEL	GYRO	MAG	GPS

Description

Bits	Name	Description
31:26	SATS_USED	Reports the number of satellites used in the position solution.
25:16	HDOP	Reports the horizontal dilution of precision (HDOP) reported by the GPS. The actual HDOP value is equal to the contents of the HDOP bits divided by 10.
15:10	SATS_IN_VIEW	Reports the number of satellites in view.
9	OVF	Overflow bit. This bit is set if the GP9 is attempting to transmit data over the serial port faster than is allowed given the baud-rate. If this bit is set, reduce broadcast rates in the COM_RATES registers.
8:7	RES	These bits are reserved.
6:5	GPS_ST	GPS Status. Reports how GPS data is being used in the filter. 1 = No GPS lock 2 = Low-quality lock, GPS unused 3 = Good
4	PRESS	This bit will be set if the pressure sensor fails to initialize on startup.
3	ACCEL	This bit will be set if the accelerometer fails to initialize on startup.
2	GYRO	This bit will be set if the rate gyro fails to initialize on startup.
1	MAG	This bit will be set if the magnetometer fails to initialize on startup.
0	GPS	This bit is set if the GPS fails to send a packet for more than two seconds. If a GPS packet is ever received, this bit is cleared.

DREG_GYRO_RAW_XY – 0x56 (86)

Summary

Contains raw X and Y axis rate gyro data

Register Contents

B3	B2	B1	B0
Gyro X (2's complement 16-bit integer)		Gyro Y (2's complement 16-bit integer)	

DREG_GYRO_RAW_Z – 0x57 (87)

Summary

Contains raw Z axis rate gyro data

Register Contents

B3	B2	B1	B0
Gyro Z (2's complement 16-bit integer)		RES	

DREG_GYRO_RAW_TIME – 0x58 (88)

Summary

Contains time at which the last rate gyro data was acquired.

Register Contents

B3	B2	B1	B0
Gyro Time (IEEE Floating Point)			

DREG_ACCEL_RAW_XY – 0x59 (89)

Summary

Contains raw X and Y axis accelerometer data.

Register Contents

B3	B2	B1	B0
Accel X (2's complement 16-bit integer)		Accel Y (2's complement 16-bit integer)	

DREG_ACCEL_RAW_Z – 0x5A (90)

Summary

Contains raw Z axis accelerometer data

Register Contents

B3	B2	B1	B0
Accel Z (2's complement 16-bit integer)		RES	

DREG_ACCEL_RAW_TIME – 0x5B (91)

Summary

Contains time at which the last accelerometer data was acquired.

Register Contents

B3	B2	B1	B0
Accel Time (IEEE Floating Point)			

DREG_MAG_RAW_XY – 0x5C (92)

Summary

Contains raw X and Y axis magnetometer data.

Register Contents

B3	B2	B1	B0
Mag X (2's complement 16-bit integer)		Mag Y (2's complement 16-bit integer)	

DREG_MAG_RAW_Z – 0x5D (93)

Summary

Contains raw Z axis magnetometer data

Register Contents

B3	B2	B1	B0
Mag Z (2's complement 16-bit integer)		RES	

DREG_MAG_RAW_TIME – 0x5E (94)

Summary

Contains time at which the last magnetometer data was acquired.

Register Contents

B3	B2	B1	B0
Mag Time (IEEE Floating Point)			

DREG_PRESSURE_RAW – 0x5F (95)

Summary

Contains raw absolute pressure data.

Register Contents

B3	B2	B1	B0
Absolute pressure (32-bit 2's complement integer)			

DREG_PRESSURE_TIME – 0x60 (96)

Summary

Contains time at which the last absolute pressure data was acquired.

Register Contents

B3	B2	B1	B0
Pressure Time (IEEE Floating Point)			

DREG_TEMPERATURE_RAW1 – 0x61 (97)

Summary

Contains raw temperature output from the accelerometer, magnetometer, and rate gyro IC

Register Contents

B3	B2	B1	B0
Temperature (IEEE Floating Point)			

DREG_TEMPERATURE_RAW2 – 0x62 (98)

Summary

Contains raw temperature from the absolute pressure IC.

Register Contents

B3	B2	B1	B0
Temperature (IEEE Floating Point)			

DREG_TEMPERATURE_TIME – 0x63 (99)

Summary

Contains time at which the last temperature was acquired.

Register Contents

B3	B2	B1	B0
Temperature time (IEEE Floating Point)			

DREG_GYRO_PROC_X – 0x64 (100)

Summary

Contains the actual measured angular rate in degrees/s after calibration has been applied.

Register Contents

B3	B2	B1	B0
Gyro X (IEEE Floating Point)			

DREG_GYRO_PROC_Y – 0x65 (101)

Summary

Contains the actual measured angular rate in degrees/s after calibration has been applied.

Register Contents

B3	B2	B1	B0
Gyro Y (IEEE Floating Point)			

DREG_GYRO_PROC_Z – 0x66 (102)

Summary

Contains the actual measured angular rate in degrees/s after calibration has been applied.

Register Contents

B3	B2	B1	B0
Gyro Z (IEEE Floating Point)			

DREG_GYRO_PROC_TIME – 0x67 (103)

Summary

Contains the time at which the last rate gyro data was measured.

Register Contents

B3	B2	B1	B0
Gyro Time (IEEE Floating Point)			

DREG_ACCEL_PROC_X – 0x68 (104)

Summary

Contains the actual measured acceleration in m/s/s after calibration has been applied.

Register Contents

B3	B2	B1	B0
Accel X (IEEE Floating Point)			

DREG_ACCEL_PROC_Y – 0x69 (105)

Summary

Contains the actual measured acceleration in m/s/s after calibration has been applied.

Register Contents

B3	B2	B1	B0
Accel Y (IEEE Floating Point)			

DREG_ACCEL_PROC_Z – 0x6A (106)

Summary

Contains the actual measured acceleration in m/s/s after calibration has been applied.

Register Contents

B3	B2	B1	B0
Accel Z (IEEE Floating Point)			

DREG_ACCEL_PROC_TIME – 0x6B (107)

Summary

Contains the time at which the acceleration was measured.

Register Contents

B3	B2	B1	B0
Accel Time (IEEE Floating Point)			

DREG_MAG_PROC_X – 0x6C (108)

Summary

Contains the actual measured magnetic field after calibration has been applied.

Register Contents

B3	B2	B1	B0
Mag X (IEEE Floating Point)			

DREG_MAG_PROC_Y – 0x6D (109)

Summary

Contains the actual measured magnetic field after calibration has been applied.

Register Contents

B3	B2	B1	B0
Mag Y (IEEE Floating Point)			

DREG_MAG_PROC_Z – 0x6E (110)

Summary

Contains the actual measured magnetic field after calibration has been applied.

Register Contents

B3	B2	B1	B0
Mag Z (IEEE Floating Point)			

DREG_MAG_PROC_TIME – 0x6F (111)

Summary

Contains the time at which magnetometer data was acquired.

Register Contents

B3	B2	B1	B0
Mag Time (IEEE Floating Point)			

DREG_PRESSURE_PROC – 0x70 (112)

Summary

Contains the altitude in meters as measured by the absolute pressure sensor after calibration has been applied.

Register Contents

B3	B2	B1	B0
Pressure Altitude (IEEE Floating Point)			

DREG_PRESSURE_PROC_TIME – 0x71 (113)

Summary

Contains the time at which the absolute pressure sensor was sampled.

Register Contents

B3	B2	B1	B0
Pressure Time (IEEE Floating Point)			

DREG_TEMPERATURE_PROC1 – 0x72 (114)

Summary

Contains the actual temperature as reported by the gyro, accel, mag IC.

Register Contents

B3	B2	B1	B0
Temperature (IEEE Floating Point)			

DREG_TEMPERATURE_PROC2 – 0x73 (115)

Summary

Contains the actual temperature from the pressure sensor.

Register Contents

B3	B2	B1	B0
Temperature (IEEE Floating Point)			

DREG_TEMPERATURE_PROC_TIME – 0x74 (116)

Summary

Contains the time at which the last temperature data was acquired.

Register Contents

B3	B2	B1	B0
Temperature Time (IEEE Floating Point)			

DREG_QUAT_AB – 0x75 (117)

Summary

Contains the first two components of the estimated quaternion attitude.

Register Contents

B3	B2	B1	B0
Quat A		Quat B	

Description

Bits	Name	Description
31:16	Quat A	First quaternion component. Stored as a 16-bit signed integer. To get the actual value, divide by 29789.09091.
15:0	Quat B	Second quaternion component. Stored as a 16-bit signed integer. To get the actual value, divide by 29789.09091.

DREG_QUAT_CD – 0x76 (118)

Summary

Contains the second two components of the estimated quaternion attitude.

Register Contents

B3	B2	B1	B0
Quat C		Quat D	

Description

Bits	Name	Description
31:16	Quat C	Third quaternion component. Stored as a 16-bit signed integer. To get the actual value, divide by 29789.09091.
15:0	Quat D	Fourth quaternion component. Stored as a 16-bit signed integer. To get the actual value, divide by 29789.09091.

DREG_QUAT_TIME – 0x77 (119)

Summary

Contains the time that the quaternion attitude was measured

Register Contents

B3	B2	B1	B0
Quaternion Time (IEEE Floating Point)			

DREG_EULER_PHI_THETA – 0x78 (120)

Summary

Contains the pitch and roll angle estimates.

Register Contents

B3	B2	B1	B0
Phi (roll)		Theta (Pitch)	

Description

Bits	Name	Description
31:16	Phi (roll)	Roll angle. Stored as a 16-bit signed integer. To get the actual value, divide by 5215.18917.
15:0	Theta (pitch)	Pitch angle. Stored as a 16-bit signed integer. To get the actual value, divide by 5215.18917.

DREG_EULER_PSI – 0x79 (121)

Summary

Contains the yaw angle estimate.

Register Contents

B3	B2	B1	B0
Psi (yaw)		Unused	

Description

Bits	Name	Description
31:16	Psi (yaw)	Yaw angle. Stored as a 16-bit signed integer. To get the actual value, divide by 5215.18917.
15:0	Unused	These bits are unused

DREG_EULER_TIME – 0x7A (122)

Summary

Contains the time that the Euler Angles were measured.

Register Contents

B3	B2	B1	B0
Euler Time (IEEE Floating Point)			

DREG_POSITION_N – 0x7B (123)

Summary

Contains the measured north position in meters from the latitude specified in CREG_HOME_NORTH.

Register Contents

B3	B2	B1	B0
North Position (IEEE Floating Point)			

DREG_POSITION_E – 0x7C (124)

Summary

Contains the measured east position in meters from the longitude specified in CREG_HOME_EAST.

Register Contents

B3	B2	B1	B0
East Position (IEEE Floating Point)			

DREG_POSITION_UP – 0x7D (125)

Summary

Contains the measured altitude in meters from the altitude specified in CREG_HOME_UP.

Register Contents

B3	B2	B1	B0
Altitude (IEEE Floating Point)			

DREG_POSITION_TIME – 0x7E (126)

Summary

Contains the time at which the position was acquired.

Register Contents

B3	B2	B1	B0
Position Time (IEEE Floating Point)			

DREG_VELOCITY_N – 0x7F (127)

Summary

Contains the measured north velocity in m/s.

Register Contents

B3	B2	B1	B0
North Velocity (IEEE Floating Point)			

DREG_VELOCITY_E – 0x80 (128)

Summary

Contains the measured east velocity in m/s.

Register Contents

B3	B2	B1	B0
East Velocity (IEEE Floating Point)			

DREG_VELOCITY_UP – 0x81 (129)

Summary

Contains the measured altitude velocity in m/s.

Register Contents

B3	B2	B1	B0
Altitude Velocity (IEEE Floating Point)			

RESERVED – 0x82 (130)

This register is reserved for future use.

DREG_VELOCITY_TIME – 0x83 (131)

Summary

Contains the time at which the velocity was measured.

Register Contents

B3	B2	B1	B0
Velocity Time (IEEE Floating Point)			

DREG_GPS_LATITUDE – 0x84 (132)

Summary

Contains the GPS-reported latitude in degrees.

Register Contents

B3	B2	B1	B0
GPS Latitude (IEEE Floating Point)			

DREG_GPS_LONGITUDE – 0x85 (133)

Summary

Contains the GPS-reported longitude in degrees.

Register Contents

B3	B2	B1	B0
GPS Longitude (IEEE Floating Point)			

DREG_GPS_ALTITUDE – 0x86 (134)

Summary

Contains the GPS-reported altitude in meters.

Register Contents

B3	B2	B1	B0
GPS Altitude (IEEE Floating Point)			

DREG_GPS_COURSE – 0x87 (135)

Summary

Contains the GPS-reported course in degrees.

Register Contents

B3	B2	B1	B0
GPS Course (IEEE Floating Point)			

DREG_GPS_SPEED – 0x88 (136)

Summary

Contains the GPS-reported speed in m/s.

Register Contents

B3	B2	B1	B0
GPS Speed (IEEE Floating Point)			

DREG_GPS_TIME – 0x89 (137)

Summary

Contains the GPS-reported time in seconds from the last epoch.

Register Contents

B3	B2	B1	B0
GPS Time (IEEE Floating Point)			

DREG_GPS_DATE – 0x8A (138)

Summary

Contains the GPS-reported date.

Register Contents

B3	**B2**	**B1**	**B0**
RES	Year	Month	Day

DREG_GPS_SAT_1_2 – 0x8B (139)

Summary

Contains satellite ID and SNR for satellites 1 and 2.

Register Contents

B3	B2	B1	B0
Sat1 ID	Sat1 SNR	Sat2 ID	Sat2 SNR

Description

Bits	Name	Description
31:24	Sat1 ID	ID of satellite
23:16	Sat1 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver
15:8	Sat2 ID	ID of satellite
7:0	Sat2 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver

DREG_GPS_SAT_3_4 – 0x8C (140)

Summary

Contains satellite ID and SNR for satellites 3 and 4.

Register Contents

B3	B2	B1	B0
Sat3 ID	Sat3 SNR	Sat4 ID	Sat4 SNR

Description

Bits	Name	Description
31:24	Sat3 ID	ID of satellite
23:16	Sat3 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver
15:8	Sat4 ID	ID of satellite
7:0	Sat5 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver

DREG_GPS_SAT_5_6 – 0x8D (141)

Summary

Contains satellite ID and SNR for satellites 5 and 6.

Register Contents

B3	B2	B1	B0
Sat5 ID	Sat5 SNR	Sat6 ID	Sat6 SNR

Description

Bits	Name	Description
31:24	Sat5 ID	ID of satellite
23:16	Sat5 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver
15:8	Sat6 ID	ID of satellite
7:0	Sat6 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver

DREG_GPS_SAT_7_8 – 0x8E (142)

Summary

Contains satellite ID and SNR for satellites 7 and 8.

Register Contents

B3	B2	B1	B0
Sat7 ID	Sat7 SNR	Sat8 ID	Sat8 SNR

Description

Bits	Name	Description
31:24	Sat7 ID	ID of satellite
23:16	Sat7 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver
15:8	Sat8 ID	ID of satellite
7:0	Sat8 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver

DREG_GPS_SAT_9_10 – 0x8F (143)

Summary

Contains satellite ID and SNR for satellites 9 and 10.

Register Contents

B3	B2	B1	B0
Sat9 ID	Sat9 SNR	Sat10 ID	Sat10 SNR

Description

Bits	Name	Description
31:24	Sat9 ID	ID of satellite
23:16	Sat9 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver
15:8	Sat10 ID	ID of satellite
7:0	Sat10 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver

DREG_GPS_SAT_11_12 – 0x90 (144)

Summary

Contains satellite ID and SNR for satellites 11 and 12.

Register Contents

B3	B2	B1	B0
Sat11 ID	Sat11 SNR	Sat12 ID	Sat12 SNR

Description

Bits	Name	Description
31:24	Sat11 ID	ID of satellite
23:16	Sat11 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver
15:8	Sat12 ID	ID of satellite
7:0	Sat12 SNR	Signal-to-Noise Ratio of satellite as reported by GPS receiver

DREG_GYRO_BIAS_X – 0x91 (145)

Summary

Contains the estimated x-axis gyro bias

Register Contents

B3	B2	B1	B0
Gyro X Bias Estimate (IEEE Floating Point)			

DREG_GYRO_BIAS_Y – 0x92 (146)

Summary

Contains the estimated y-axis gyro bias

Register Contents

B3	B2	B1	B0
Gyro Y Bias Estimate (IEEE Floating Point)			

DREG_GYRO_BIAS_Z – 0x93 (147)

Summary

Contains the estimated z-axis gyro bias

Register Contents

B3	B2	B1	B0
Gyro Z Bias Estimate (IEEE Floating Point)			

DREG_ BIAS_X_VARIANCE – 0x94 (148)

Summary

Contains the filter variance for the x-axis gyro bias estimate.

Register Contents

B3	B2	B1	B0
Gyro X Bias Estimate Variance (IEEE Floating Point)			

DREG_ BIAS_Y_VARIANCE – 0x95 (149)

Summary

Contains the filter variance for the y-axis gyro bias estimate.

Register Contents

B3	B2	B1	B0
Gyro Y Bias Estimate Variance (IEEE Floating Point)			

DREG_ BIAS_Z_VARIANCE – 0x96 (150)

Summary

Contains the filter variance for the z-axis gyro bias estimate.

Register Contents

B3	B2	B1	B0
Gyro Z Bias Estimate Variance (IEEE Floating Point)			

DREG_ QUAT_A_VARIANCE – 0x97 (151)

Summary

Contains the filter variance for the quaternion ‘a’ element.

Register Contents

B3	B2	B1	B0
Quaternion a Variance (IEEE Floating Point)			

DREG_ QUAT_B_VARIANCE – 0x98 (152)

Summary

Contains the filter variance for the quaternion ‘b’ element.

Register Contents

B3	B2	B1	B0
Quaternion b Variance (IEEE Floating Point)			

DREG_ QUAT_C_VARIANCE – 0x99 (153)

Summary

Contains the filter variance for the quaternion ‘c’ element.

Register Contents

B3	B2	B1	B0
Quaternion c Variance (IEEE Floating Point)			

DREG_ QUAT_D_VARIANCE – 0x9A (154)

Summary

Contains the filter variance for the quaternion 'd' element.

Register Contents

B3	B2	B1	B0
Quaternion d Variance (IEEE Floating Point)			

Commands

GET_FW_REVISION – 0xAA (170)

Causes the GP9 to transmit a packet containing the firmware revision string. The firmware revision is a four-byte character sequence. The first firmware release version for the GP9, for example, was "OR1A".

The address of the packet will be 0xAA. The data section of the packet will contain four bytes.

FLASH_COMMIT – 0xAB (171)

Causes the GP9 to write all configuration settings to FLASH so that they will remain when the power is cycled.

RESET_TO_FACTORY – 0xAC (172)

Causes the GP9 to load default factory settings.

ZERO_GYROS – 0xAD (173)

Causes the GP9 to measure the gyro outputs and set the output trim registers to compensate for any non-zero bias. The GP9 should be kept stationary while the zero operation is underway.

SET_HOME_POSITION – 0xAE (174)

Sets the current GPS latitude, longitude, and altitude as the home position. All future positions will be referenced to the current GPS position.

RESET_EKF – 0xB3 (179)

Resets the filter.