OPUS EMBEDDED LTD.

Embedded Piece of Art

Products: OPUS-Inertial-R Series

Product Codes: OP020-016-RI, OP020-016-RA and OP020-016-RAM

Document Type: COM Ports Firmware Interface (OPUS Proprietary Firmware Interface)

Document Revision: 0.9.2

OPUS-Inertial-R

CONTENT

COM PORT INTERFACE (UART, USB and RS232)

GENERAL INFORMATION

OPUS-Inertial-R series are set to 921600 baud with 8n1 configuration by default. Please contact to technical@opusembedded.com for further information or modification requests.

All of configuration commands starts with "$" and ends with "[CR][LF]" for standardization purposes. Configuration responses are developed accordingly.

Most of the commands have $SET or $GET structure for ease of use.

For better understanding, all commands have examples below their description. "H" means host, "M" means module for this purpose. ">" indicates the direction, which is output for the related device.

COORDINATE FRAME

Coordinate system of OPUS-Inertial-R devices are visualized in Figure-1. Positive angles are defined as counter-clockwise rotation of the related axis which are shown in the figure.

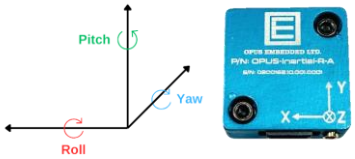

Figure-1: *Sensor Coordinate Frame (Device Top View)*

3D Orientation output is set to x, y', z'' by default. This means output configuration is achieved by first rotating about the roll axis, then rotating about the new pitch axis, finally rotating about the new yaw axis.

COMMANDS

1. Device Specific Commands

$GETID

- **Description:** Returns hardware information of the module.
- **Response:** $ID,<Device Type>,<HW Revision>,<Serial No.>

Example	Desciption
H> $GETID M> $ID,OPUS-Inertial-RA,1.0,00001	—

$GETSTATEINFO

- **Description:** Returns current state details of the device.
- **Response:** $STATEINFO,<ODR>,<Speed Status>,<Data Type Status>,<GY Cal. Status>,<MG Cal. Status>,<MG En. Status>

Example	Desciption
H> $GETSTATEINFO M> $STATEINFO,250,HS,1,Y,Y,1	Output is set to 250Hz, high-speed format, orientation output, Gyro and Magnetometer calibrated, Magnetometer enabled.

$FACTORYRESET

- **Description:** Sets the device calibration for default values. Each device is calibrated separately by OPUS.
- **Entry Structure:** $FACTORYRESET
- **Return:** $OK

Example	Desciption
H> $FACTORYRESET M> $OK	Returns to factory calibration of the specific device.

2. Commands For Output Configuration

$SETOUTCONF

- **Description:** Data output configuration. First option is speed, user can choose either high speed with "1" or low speed with "0". Second option is calibrated IMU output with "0", orientation output with "1" or both with "2". Note that in high-speed mode, current firmware only supports "orientation" output. So, user can only enter "$SETOUTCONF,1,1" for high-speed mode. If user wants calibrated IMU data, low-speed mode has to be chosen.
- **Entry Structure:** $SETOUTCONF,<Speed_Type>,<Data_Type>
- **Response:** $OUTCONF,<Speed_Type>,<Data_Type>

Example	Desciption
H> $SETOUTCONF,1,1 M> $OUTCONF,1,1	Device is configured as high-speed orientation output.
H> $SETOUTCONF,0,2 M> $OUTCONF,0,2	Device is configured as low-speed calibrated IMU + orientation output.
H> $SETOUTCONF,1,2 M> $ERROR	Device has been tried to be configured as high-speed calibrated IMU + orientation output, but it return error since it is not allowed in current firmware.

It is recommended to enter $STOP command before changing output configuration.

$GETODRINFO

- **Description:** Returns possible ODR output range. If only one output type (orientation or IMU) is selected, device returns the maximum speed of according to speed types. If both are selected, device returns the half or this value. User can consider this command as a double check. If user wants different baud rate configuration by contacting technical@opusembedded.com then the values change accordingly.
- **Response:** $ODRINFO,<Data_Type>,HS,<HS ODR Min.>,<HS ODR Max.>,LS,<LS ODR Min.>,<LS ODR Max.>

Example	Desciption
H> $GETODRINFO M> $ODRINFO,2,HS,0,0,LS,0,50	When IMU + Orientation output is selected, device doesn't give output in high-speed mode. So the values are 0 accordingly.
H> $GETODRINFO M> $ODRINFO,1,HS,0,1000,LS,0,50	Orientation output is selected, so device can output 0 to 1kHz in high-speed mode, 0 to 50Hz in low-speed mode.

$SETODR

- **Description:** Sets ODR according to input. Note that input value is calculated by the following equation:

  ODR ≈ 1024 / (n+1) **-> {n_{min}** = 0 **if** Speed_Type = 1; **n_{min}** = 19 **if** Speed_Type = 0**}**

  If input entry (High_Speed_Set or Low_Speed_Set) is below minimum, module returns to its possible minimum. Minimum values vary with the value user enters in $SETOUTCONF command. Contact to technical@opusembedded.com for fine-tuning.
- **Entry Structure:** $SETODR,<High_Speed_Set>,<Low_Speed_Set>
- **Response:** $ODR,<High_Speed_Set Value>,<Low_Speed_Set Value>

Example	Desciption
H> $SETODR,0,0 M> $ODR,1000,50	High Speed orientation output is set to 1kHz. Low Speed orientation / IMU or both outputs are set to 50Hz since n_{min} is 19.
H> $SETODR,1,127 M> $ODR,500,8	High Speed orientation output is set to 500Hz. Low Speed orientation / IMU or both outputs are set to 8Hz.

$SETMAGUSE

- **Description:** Sets Magnetometer usage. Since magnetometer is effected by magnetic disturbance, user may disable the usage of magnetometer in short terms for better performance. Please note that for first usage, magnetometer is required for proper heading calculations. Also, without magnetometer, device will have output drift in long term.
- **Entry Structure:** $SETMAGUSE,<Enable /Disable>
- **Response:** $MAGUSE<Enable /Disable>

Example	Desciption
H> $SETMAGUSE,0 M> $MAGUSE,0	Magnetometer is disabled.

3. Commands For Calibration

$GYCAL

- **Description:** Gyro calibration. When the device is powered, user can calibrate the gyroscope by entering the command and holding still until OK return (about 1 second). Device returning OK means Gyro calibration is done. Note that user can always use $FACTORYRESET for using default calibration values. Also, user must disable data output by using $STOP command before calibration setup.
- **Entry Structure:** $GYCAL
- **Response:** $OK

Example	Desciption
H> $GYCAL M> $OK	Gyroscope is calibrated.

$MGCALZ

- **Description:** Clears the magnetometer calibration sums. User must first enter this command to start magnetometer calibration. Device returning OK means magnetometer sum clear is done. Note that user can always use $FACTORYRESET for using default calibration values. Also, user must disable data output by using $STOP command before calibration setup.
- **Entry Structure:** $MGCALZ
- **Response:** $OK

Example	Desciption
H> $MGCALZ M> $OK	Magnetometer calibration sums are cleared.

$MGCALR

Description: Device takes a single magnetometer measurement and add it to magnetometer calibration sum. Note that user can always use $FACTORYRESET for using default calibration values. Also, user must disable data output by using $STOP command before calibration setup.

- **Entry Structure:** $MGCALR
- **Response:** $OK

Example	Desciption
H> $MGCALR M> $OK	Magnetometer calibration sampled (1x). For best performance, it is recommended to repeat this procedure for 8-axis as explained in RECOMMENDED METHOD FOR MAGNETOMETER CALIBRATION.

$MGCALS

- **Description:** Stores the magnetometer calibration values. these values are calculated by dividing the magnetometer calibration sums by the number of measurements. Note that user can always use $FACTORYRESET for using default calibration values. Also, user must disable data output by using $STOP command before calibration setup.
- **Entry Structure:** $MGCALS
- **Response:** $OK

Example	Desciption
H> $MGCALS M> $OK	Magnetometer calibration is stored.

$SAVECAL

- **Description:** Saves calibration data for future uses. Note that user can always use $FACTORYRESET for using default calibration values. Also, user must disable data output by using $STOP command before calibration setup.
- **Entry Structure:** $SAVECAL
- **Return Structure:** $OK

Example	Desciption
H> $SAVECAL M> $OK	Gyro and magnetometer calibration is saved.

$GETCALINFO

- **Description:** Returns calibration information of the related power-up session. Please note that if no calibration is done by the user in that session, values are going to be 0. This doesn't necessarily mean whether devices are calibrated or not. This command gives the information to the user whether the calibration is done or not in that power-up session.
- **Response:** $CALINFO,<Gyro cal. info>,<Mag cal. info>

Example	Desciption
H> $GETCALINFO M> $CALINFO,1,1	Means that device is calibrated in that power-up session.
H> $GETCALINFO M> $CALINFO,0,0	Means that device isn't calibrated in that session session. This doesn't mean that device is never calibrated.

Recommended magnetometer calibration procedure is as follows:

Step-1 → Clear the magnetometer calibration sum using MGCALZ.

Step-2 → Place the module horizontally and take a measurement using MGCALR.

Step-3 → Rotate the module 90 degrees and take another measurement using MGCALR.

Step-4 → Rotate the module 90 degrees twice more and take measurements at each step.

Step-5 → Rotate the module upside down. Take 4 more measurements at 90 degree angles.

Step-6 → Store the calibration values using MGCALS.

Step-7 → Save calibration parameters using SAVECAL.

Step-8 → Validate whether calibration is done by checking GETCALINFO.

4. Commands For Data Output

$GO

- **Description:** Starts outputting data according to the configuration.
- **Entry Structure:** $GO
- **Return Option #1:** If High-Speed is chosen via $SETOUTCONF, packet consists of 14 bytes. 32 bits of pitch, followed by 32 bits of roll and 32 bits of yaw, followed by ASCII characters CR and LF. Pitch, roll and yaw are angles in radians given in IEEE754 floating point format.
- **Return Option #2:** If Low-Speed is chosen via $SETOUTCONF;
  - Orientation data return packet consists of pitch, roll and yaw are angles in radians given with 4 digits after decimal point and output is set to following format: $ORI,<Pitch_value>,<Roll_value>,<Yaw_value>[CR][LF].
  - Calibrated IMU data return packet consists of 3-axis gyroscope value in angular velocity (dps) with 4 digits after decimal point, 3-axis magnetometer readings in milli-Gauss unit (integer), 3-axis accelerometer value in gravitational acceleration unit (g=9.81m/s^2), with 3 digits after decimal point. Calibrated IMU information is outputted with following format: $IMU,$GY_X$,$GY_Y$,$GY_Z$,$MAG_X$,$MAG_Y$,$MAG_Z$,$ACC_X$,$ACC_Y$,$ACC_Z$[CR][LF].

Example	Desciption
H> $GO M> AB E0 5C BF AE 3C F7 BE 41 FB EA BF 0D 0A ..	Means -0.862803 Pitch, -0.482884 Roll, -1.83579 Yaw compliant with the format explained in Return Option #1. In this example, Speed_Type is selected as 1 (High Speed) and Data_Type is selected as 1 (Orientation).
H> $GO M> $ORI,-0.0725,0.0716,0.4618 $IMU,0.0023,-0.0003,0.0026,83,-12,-358,-0.097,-0.033,0.993 ..	Low-speed mode outputs compliant with the format explained in Return Option #2. In this example, Speed_Type is selected as 0 (Low Speed) and Data_Type is selected as 2 (IMU + Orientation).

Current firmware of OPUS-Inertial-R doesn't support IMU data in High Speed mode. For IMU information, please use low speed mode.

$STOP

- **Description:** Stops outputting data until the next $GO command.
- Entry Structure: $STOP
- Return: $OK

Example	Desciption
H> $STOP M> $OK	Stops outputting data.

USE SCENARIOS OVER COM PORTS

1. Example #1:

User can output 500Hz orientation data in high-speed output format and calibrate the device for the specific environment with the commands below:

Step	Command	Note
#1	H> $STOP M> $OK	Stop the output in case of device is in runtime. Otherwise, this command is not needed.
#2	H> $SETOUTCONF,1,1 M> $OUTCONF,1,1	Speed_Type is set as high-speed and Data_Type is set as orientation.
#3	H> $SETODR,1,0 M> $ODR,500,50	ODR is set to 500 with the following equation, where **n = 1**: **ODR** ≈ 1024 / (n+1) **-> {nmin** = 0 **if** Speed_Type = 1; **nmin** = 19 **if** Speed_Type = 0**}**
#4	H> $SETMAGUSE,1 M> $MAGUSE,1	For doublecheck purposes, MAGUSE is set to 1. (If it is already set, then this command is not needed.)
#5	H> $GYCAL M> $OK	Gyroscope is calibrated. (If it is already calibrated or user wants to use the defaults, then this command is not needed.)
#6	H> $MGCALZ M> $OK	Magnetometer calibration sums are cleared. (If it is already cleared or user wants to use the defaults, then this command is not needed.)
#7	H> $MGCALR M> $OK	Single magnetometer calibration sum is done. It is recommended for the user to calibrate the magnetometer by rotate and sum 8 times as explained in RECOMMENDED METHOD FOR MAGNETOMETER CALIBRATION for the best perfomance. (If magnetometer is already calibrated or user wants to use the defaults, then this command is not needed.)
#8	H> $MGCALS M> $OK	Magnetometer calibration sums are stored and magnetometer is calibrated. (If it is already cleared or user wants to use the defaults, then this command is not needed.)
#9	H> $SAVECAL M> $OK	Gyroscope and Magnetometer calibration is saved.
#10	H> $GETCALINFO M> $CALINFO,1,1	User can check and get the calibration done information from this command.
#11	H> $GO M> $ AB E0 5C BF AE 3C F7 BE 41 FB EA BF 0D 0A … …	Device starts to output 500Hz orientation data in high-speed output format with the calibration that user made.

2. Example #2:

User can output 50Hz IMU + Orientation data, low-speed output format with standard factory calibration values with the commands below:

Step	Command	Note
#1	H> $STOP M> $OK	Stop the output in case of device is in runtime. Otherwise, this command is not needed.
#2	H> $SETOUTCONF,0,2 M> $OUTCONF,0,2	Speed_Type is set as low-speed and Data_Type is set to IMU + Orientation.
#3	H> $SETODR,0,19 M> $ODR,1000,50	ODR is set to 50Hz with the following equation, where **n = 19**: **ODR** ≈ 1024 / (n+1) **-> {nmin** = 0 **if** Speed_Type = 1; **nmin** = 19 **if** Speed_Type = 0**}**
#4	H> $SETMAGUSE,1 M> $MAGUSE,1	For doublecheck purposes, MAGUSE is set to 1. (If it is already set, then this command is not needed.)
#5	H> $GETCALINFO M> $CALINFO,0,0	Means that no calibration is done in that runtime. If user is not sure whether there's any calibration done in prior power-up's, then it is recommended to use **$FACTORYRESET** after step #5 and return the calibration to factory settings.
#6	H> $GO M> $ORI,-0.0725,0.0716,0.4618 $IMU,0.0023,-0.0003,0.0026,83,-12,-358,-0.097,-0.033,0.993 … …	Device starts to output 50Hz IMU + Orientation data in low-speed output format with factory calibration.