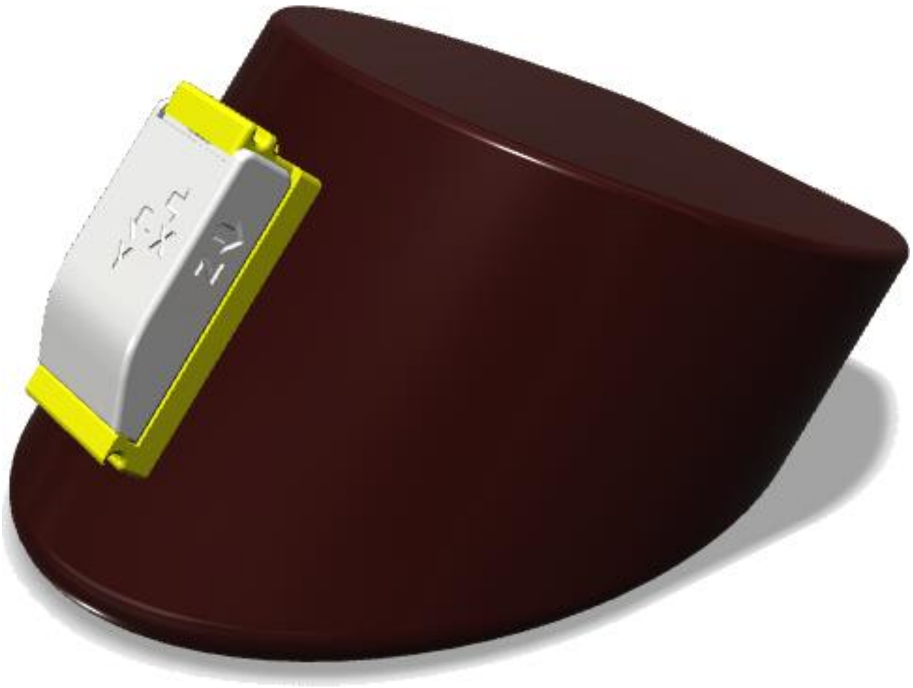
PraxSys Pty. Ltd.

18 Erskine Avenue,
Cheltenham. 3192.
Victoria. Australia.

Telephone : +61 3 9584 9360
ABN: 20 055 511 585

# Inertial Measurement Unit (IMU) v3.7



## *User Guide*

# PraxSys Pty. Ltd.

## Inertial Measurement Unit (IMU) v3.7

## *User Guide*

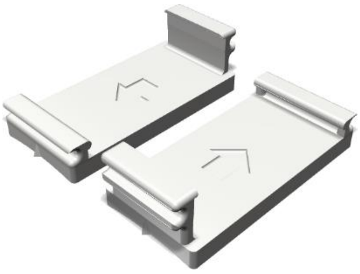
The PraxSys Inertial Measurement Unit (IMU) is a battery-powered data recorder incorporating inertial sensors for measuring tri-axial linear acceleration and rotational speed. IMU's also have a programmable-gain differential analog input, multiple digital input/output points, and supports SPI, I²C and UART serial communications protocols with external devices. Data is written to 1Gb flash memory at rates up to 2kHz. The IMU connects to a Windows® computer (PC) via its USB-C port using standard USB2.0 USB-C cable for management and charging. The USB-C port provides the access point for external devices during recording. A colour LED, visible through the IMU case, indicates its status and a real-time-clock (RTC) maintains an accurate clock/calendar. This guide describes the use of the IMU's Windows® PC software IMU(v3_7_#) for IMU configuration, logging, data retrieval and processing.

**Equipment**

Items of equipment, and how they are referred to within this guide, are:

Recorder Module
"IMU"

Blank Module
"Blank"



(Hoof) IMU Mount
"Mount"

Elastic Ring "Ring":
O-Ring Size BS019
or BS020 (supplier)

USB-A to USB-C
Cable (USB 2.0)
"Cable" (supplier)

USB Hub
"Hub" (supplier)

USB-C Dust Cap
"Cap" (supplier)


Software USB
flash drive

# Setup and Warnings

*USB-C USB2.0 Cable*

IMU's employ a 24-pin USB-C connector, however, some IMU-proprietary pin functions may not comply with the USB Type-C® Cable and Connector Specification.

Except for IMU-proprietary cables, any connection to the IMU should only use a standard **USB2.0** cable (power/data communications) to avoid damage to the IMU or connected device.

Both the USB-A type and USB-C type connectors of the supplied USB cables are reversible; that is, they can be inserted into their respective ports regardless of orientation.

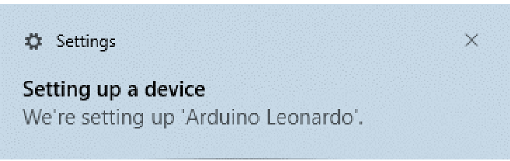
*IMU Battery*

The IMU is powered by a single-cell LiPo battery and precautions for this battery type should be observed during IMU storage and transport, or if it is damaged. The battery is charged (via an internal charge management system) whenever the IMU is connected to a computer or USB charger. The battery has a nominal operating voltage range of 3.5V to ~4.1V; IMU battery voltage can be obtained using one of the *IMU Information* commands. A fully charged battery should provide at least 2 hours of recording.

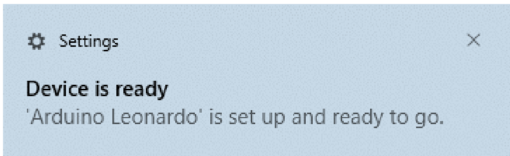
IMU batteries should be charged monthly when not in use.
Up to 6 IMU's can be charged from a PC via the Hub without the supplied Hub power pack.

*IMU Windows® Driver Installation*

An IMU connected to a Windows® PC will be detected as a USB device. When an IMU is first connected it will be recognized as an "Arduino Leonardo" (the IMU's CPU bootloader) as shown following (on a Windows® 10 PC); allow a few moments for Windows® to register the IMU.




... a few moments ...




This process will occur once only if the IMU is re-connected to the same PC USB port. It is recommended to always connect IMU's via the supplied USB Hub to the same PC USB port. For initial setup, connect the Hub to the PC then connect each IMU one at a time to the Hub allowing time for each IMU to be registered in turn. The USB device registration process should be performed before first starting the IMU software. Note: IMU as a USB device registration can be confirmed using the Windows® Device Manager where IMU's will be listed as "USB Serial Device (COM##)" under the "Ports (COM & LPT)" hardware group.

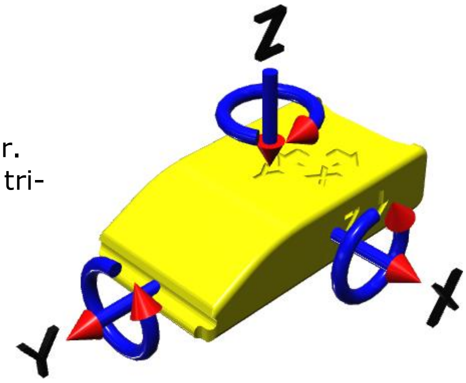
*Software Installation*

To install the IMU software, run the "setup.exe" program on the supplied USB flash drive and follow the instructions. Gnuplot is a public-domain graphing utility used by the IMU software to generate data plots. Gnuplot must be installed separately by running the "GNUPlot_Install_Win##.bat" batch file on the supplied USB flash drive for 32-bit or 64-bit PC's.

*User Guide Nomenclature*

In this User Guide references to IMU software screens or screen controls (text-boxes, check-boxes, option-buttons, etc.) are shown in *italics*; references to command buttons are shown with the buttons [Caption] shown in square brackets. Reference to keyboard keys are shown in angle brackets; for example, the Enter key is shown as <Enter>, and <Ctrl>A indicates pressing the Ctrl and A keys together. Reference to other Guide sections are shown in *italics* preceded by §.

# IMU Hardware




The IMU incorporates the following inertial sensors:

X1: High-range ±200g tri-axial linear accelerometer.
X2: Low-range ±4g, ±8g, ±16 or ±30g tri-axial linear accelerometer.
G2: Selectable ±500°/sec, ±1000°/sec, ±2000°/sec or ±4000°/sec tri-axial gyroscope (rotational speed).

The illustration shows the axis convention for the inertial sensors; the gyroscope rotational directions follow the "right-hand rule" about their associated linear direction. The axis convention is also molded into the IMU case.

The IMU connects to a Windows® PC via its USB-C port using standard USB2.0 USB-C cable which also charges the IMU.

The USB-C port also provides a proprietary connection point for a programmable-gain differential analog input, multiple digital input/output points, and SPI, I²C and UART serial communications protocols with external devices. For further information regarding IMU USB-C connector pinouts, refer to *§ IMU USB-C Port Pinouts*.

When the IMU is used in dusty or damp environments, a Dust Cap should be fitted to its USB-C port to avoid contaminant ingress; the IMU must not be exposed to liquids. If the USB-C port becomes contaminated it can be cleaned with low-pressure compressed air or non-flammable compressed gas such as a Dust Remover Spray Can.

IMU's have a colour LED visible through the IMU case for status annunciation, typically indicating:

- IMU idle, sleep pending disconnection, error.
- IMU logging armed.
- IMU logging.
- User *Manual Trigger* input (not IMU controlled)

By default, IMU's flash red every 5 seconds when idle or, after 30 minutes of inactivity, show red continuously as the IMU enters sleep mode pending disconnection from a PC or charger. When asleep and disconnected from a PC an IMU must be re-connected to a PC to awaken it.

The IMU records sensor measurements in a 1Gb non-volatile Flash memory. Data written to this memory type is not lost when the IMU powers off but must be explicitly erased before the memory can be re-used. Measuring tri-axial acceleration and gyroscope at 2000 scans/sec, this memory capacity will hold approximately 1.5 hours of recorded data.

The IMU incorporates a real-time-clock (RTC) which maintains an accurate clock/calendar even when the IMU is powered-off. The IMU's RTC is the date/time reference for all recorded tests and can be synchronised with a PC clock as a common datum for all connected IMU's.

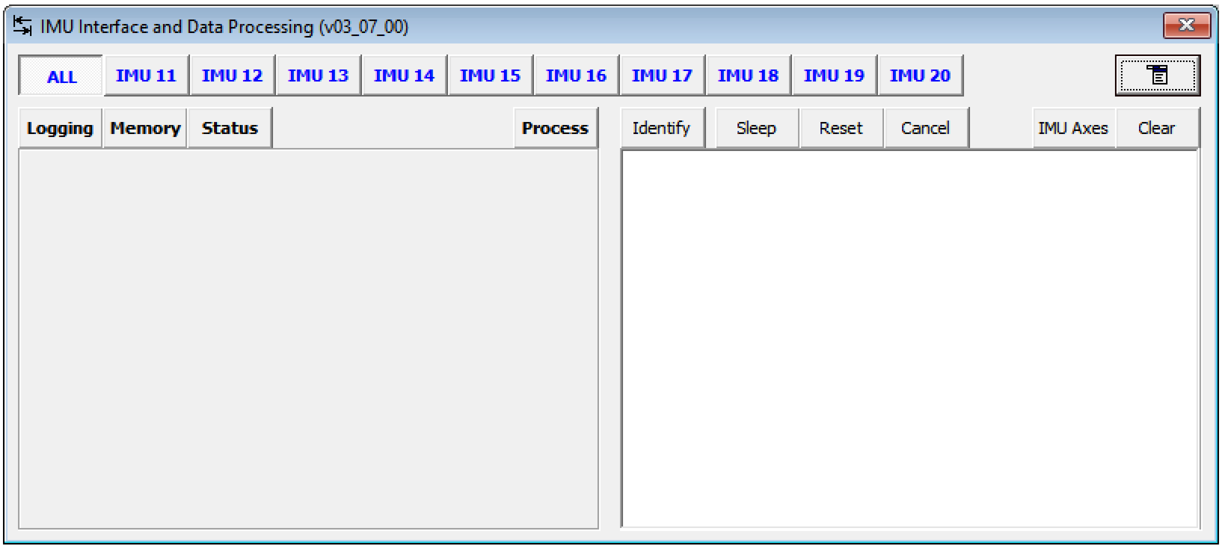
# IMU Windows® PC Software

The general process flow using the IMU software to conduct tests with IMU's is:

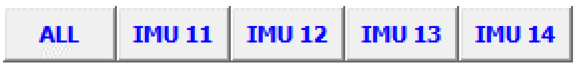
1. Start IMU software IMU(v3_7_#).
2. Connect IMU's to the PC where they are automatically detected by the IMU software.
3. Configure the IMU's for logging (if required).
4. Initiate logging whereby the IMU enters the logging armed state (IMU shows yellow).
5. Disconnect the IMU's from PC and mount for testing.
6. During logging (IMU flashing green) conduct test measurements.
   The IMU briefly shows red when logging has finished.
7. Re-connect IMU's to the PC.
8. Upload IMU's recorded data to a binary format BIN (*.bin) file.
9. Process a BIN file in engineering units to a comma-separated-variable CSV (*.csv) text file.
10. Erase IMU's memory.
11. Repeat to step 3, or
12. Finish testing, exit IMU software, disconnect IMU's as required.

## Main Screen

Starting the IMU software shows its *Main Screen* from which process steps can be performed.



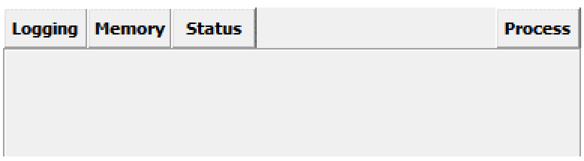

*IMU Toolbar*




The *IMU Toolbar* across the top of the main screen contains an [ALL] button and a button for each IMU detected by the IMU software referenced and ordered by IMU number. When connecting IMU's allow a few seconds for the IMU's to be detected and identified by the IMU software before appearing on the *IMU Toolbar*.

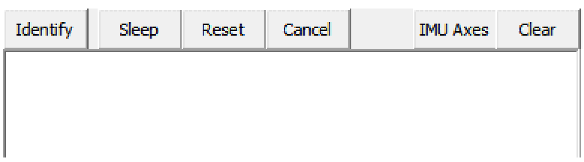
Selecting [ALL] will broadcast commands to all listed IMU's. Selecting an individual IMU's button will issue commands to the selected IMU; this is referred to as *All/Selected IMU* in this Guide.

*Command and Communication Panels*




Below the *IMU Toolbar*, the left side of the screen is a *Command Panel* including buttons for the [Logging], [Memory], [Status] and [Process] command groups, and an area where individual settings and commands related to a command group will be displayed.

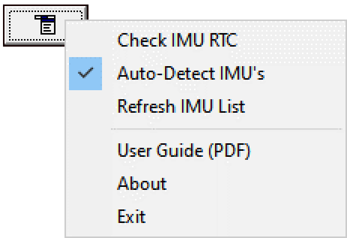
The right side of the screen contains miscellaneous command buttons above a *Communications Panel* listing time-stamped



communications between the IMU software and IMU's. An IMU should reply to any command in some form. When [ALL] is selected in the *IMU Toolbar* this panel will show communications with all IMU's; when an individual IMU is selected the communications panel will be filtered to show only communications with the selected IMU. Click [Clear] at any time to clear the listed communications.

*Main Menu*

Of the other miscellaneous buttons, [Identify] will command All/Selected IMU to identify itself by flashing red/yellow for a few seconds. Similarly, [Sleep] and [Reset] will command All/Selected IMU to enter sleep mode pending disconnection, or perform a complete hardware reset, respectively. The [IMU Axes] button will illustrate the IMU inertial axis system over the *Communications Panel*.



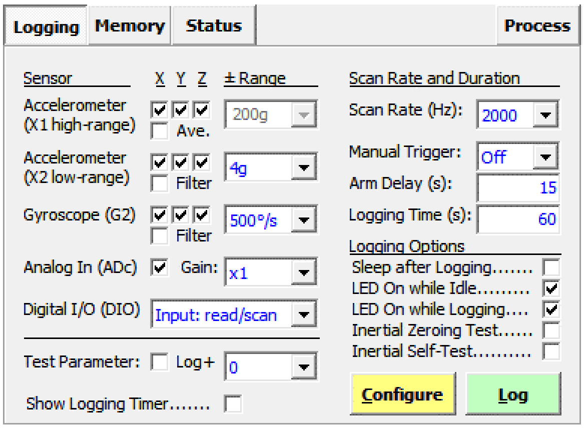

Clicking the *Main Menu* button in the top-right corner of the *Main Screen* will display a pop-up menu.

When ticked, the *Check IMU RTC* menu item will check whether a newly connected IMU's real-time clock (RTC) is current with the PC's clock. Leaving this item unticked speeds up the detection of multiple IMU's but will not automatically detect discrepancies between the PC time and IMU's RTC's.

Ticking *Auto-Detect IMU's* will automatically update the *IMU Toolbar* with available IMU's as they are connected and dis-connected from the PC. *Refresh IMU List* will manually refresh the list of available IMU's in the *IMU Toolbar* and must be used if *Auto-Detect IMU's* is unticked.

Selecting the *User Guide (PDF)* menu item will display a PDF copy of this User Guide, while *Exit* will shut-down the IMU software (as will the customary Windows® Close button).

## Log Settings and Commands




When any IMU's are connected, the [Logging] commands group button will be enabled and can be clicked to display IMU logging configuration settings and commands.


The logging configuration is sent to and saved in the IMU. As such, it does not need to be (re)sent between logging runs or test sessions unless changed. If any logging settings are changed, the [Configure] button shows a yellow background indicating that the logging configuration must be updated in the IMU before use.


To initiate IMU logging, described below, click the [Log] button.

Clicking [Log] with [ALL] IMU's will simultaneously initiate logging in all connected IMU's.

*Sensor Channels Configuration*

Settings under the Sensor heading allow individual axis (X, Y, Z) of the inertial sensors and the analog input (herein referred to as input channels), and one of the (general-purpose) digital input/output points (GPIO) to be enabled for logging.

The full-scale range of the high-range linear accelerometer X1 is fixed at ±200g, but the full-scale ranges of the low-range linear accelerometer X2 (±4g, ±8g, ±16 or ±30g) and gyroscope G2 (±500°/sec, ±1000°/sec, ±2000°/sec or ±4000°/sec) can be changed as required. Regardless of the logging *Scan Rate*, the X1 sensor generates a new reading at a rate of 3.2kHz. Ticking the *Ave.* check-box associated with the X1 sensor will average all X1 readings (taken at 3.2kHz) generated between successive logging scans to produce the logged value. For example, if the IMU *Scan Rate* is 500Hz, between 6 and 7 X1 readings will be averaged to produce the X1 logged value. X2 and G2 generate new readings at a 9kHz rate. Ticking their *Filter* check-boxes will enable a sensor-level 1kHz low-pass filter on these sensors also limiting their output rate to 1kHz regardless of the IMU *Scan Rate*.

With the *Analog Input* enabled for logging, a range of signal gains between x1 and x128 (suitable for quarter-bridge inputs) can be selected to be applied to the analog input signal level. The status of the Digital I/O point is always recorded. It can be configured as a (digital) Input, or as a (digital) Output producing a 50% duty square wave at half the IMU *Scan Rate*, a pulse which is active/high for 1 scan period every 1 second, or a pulse which active/high for 1 second every 10 seconds.

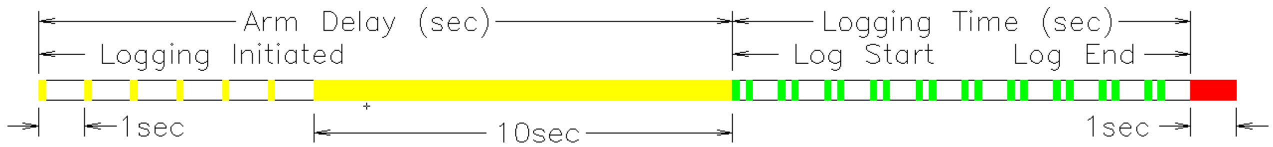
The *Test Parameter* is a general-purpose byte value (0 to 255) which is logged with each recording. For example, it could be used to indicate a test number. If the *Log+* check-box is ticked the *Test Parameter* value in the IMU will be automatically incremented at the commencement of logging.

Ticking *Show Logging Timer* will display a large font logging timer over the *Communications Panel* counting down the configured IMU log timing when logging has been initiated.

*Logging Scan Rate and Duration*

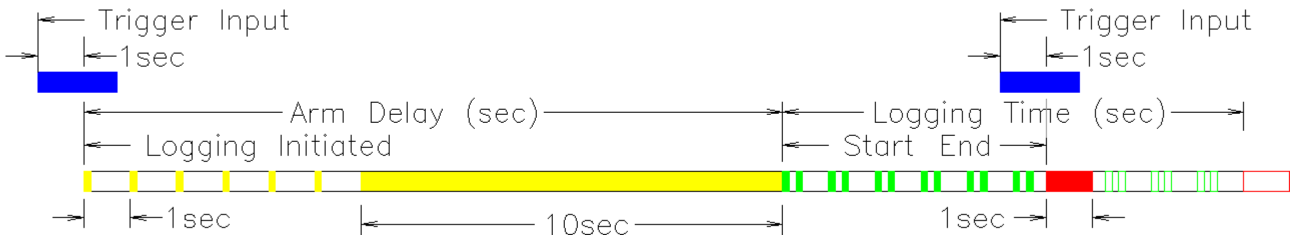
Settings under the Scan Rate and Duration heading control the rate and duration at which an IMU records (logs) sensor readings. The *Scan Rate* setting controls the rate at which the IMU stores sensor readings and can be set to 250Hz, 500Hz, 1kHz or 2kHz.

Logging can be initiated from the IMU software, or by activating a digital input pin on the IMU referred to as the *Manual Trigger* input. With the *Manual Trigger* setting Off, logging is initiated by clicking the [Log] button; logging then follows the timing illustrated below (using a 15 second *Arm Delay* and 10 second *Logging Time*).




For a period of the *Arm Delay* setting the IMU is armed for logging. During this time the IMU shows a single yellow flash every second, except for last 10 seconds before logging starts during which the IMU shows continuous yellow. The arm delay time is used for disconnecting the IMU from the PC and mounting it in preparation for a test. After the arm delay has expired logging starts and continues for the period of the *Logging Time* setting. During logging the IMU shows double green flashes every second. At the end of the logging period, logging stops, the IMU shows continuous red for 1 second, then returns to its idle state; one test has been recorded.

Alternatively, logging can be both initiated and stopped using the IMU's *Manual Trigger* input; logging this way follows the timing illustrated below (using a 1 second *Manual Trigger* delay, a 15 second *Arm Delay* and 10 second *Logging Time*).




To perform this method of logging choose a *Manual Trigger* delay of 1, 5 or 10 seconds and [Configure] the IMU; clicking the [Log] button is not required. Disconnect the IMU from the PC, connect pushbutton switch to the IMU's *Manual Trigger* input, and mount the IMU in preparation for a test. To initiate logging, press and hold the *Manual Trigger* pushbutton for a least the *Manual Trigger* delay setting. While the pushbutton can be pressed for longer, logging will be initiated immediately the *Manual Trigger* delay has passed. Like logging initiated with the [Log] button, the IMU will now pause for the *Arm Delay* period before logging commences. Logging can be stopped at any time (before the *Logging Time* expires) by again pressing and holding the *Manual Trigger* input for a minimum of the *Manual Trigger* delay period. Note, while the IMU's *Manual Trigger* input is held the IMU will show a continuous blue colour. The state of the *Manual Trigger* input is always recorded so it can also be used to manually flag events during the test provided it is not held longer than the *Manual Trigger* delay period (which would halt the test).

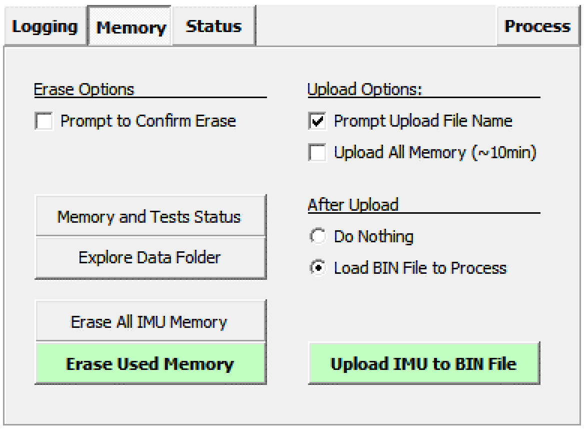
*Logging Options*

Various Logging Options are also provided. Ticking *Sleep After Logging* will put the IMU to sleep after logging stops rather than returning to an idle state (for a maximum of 30 minutes). *LED On while Idle* will cause the IMU to flash red every 5 seconds to indicate an idle state; *LED On while Logging* will cause the IMU to show the double green flashes every second while logging.

Ticking the *Inertial Zeroing Test* or *Inertial Self Test* check-boxes initiates particular test sequences for the inertial sensors for the next logging run. The *Inertial Zeroing Test* causes the IMU to pause recording for the first 5 seconds of every successive 10 second period throughout the *Logging Time*; logging follows the timing illustrated below (using a 20 second *Logging Time*).


The pause allows the IMU to be reorientated such that a 60 second *Logging Time* would permit each inertial axis to be subject to + and - Earth's gravity; the IMU must be stationary while logging is otherwise active. While paused the IMU shows continuous red; otherwise showing its customary double green flash while recording. Averaging all test data for each inertial sensor axis individually produces the "zero" value for an axis be it 0g or 0°/sec for accelerometers or gyroscopes, respectively. During the *Inertial Self Test* the IMU activates each inertial sensors self-test mode whereby a sensor artificially generates an output simulating a physical measurement. While self-test output values are not calibrated, a significant change in output value between separate self-tests may indicate sensor damage. A self-test requires a 15 second *Logging Time* and the IMU must be entirely stationary during the self-test. Note: these two test types automatically cancel after one test.

## Memory Commands




When any IMU's are connected, the [Memory] commands group button will be enabled and can be clicked to display IMU memory commands and options. Memory operations are divided between erasing, and uploading data from, the IMU's flash memory.

Memory commands can be sent to *All/Selected IMU's*; care should be exercised when sending the erase command to [ALL] IMUs.

Clicking [Memory and Tests Status] will command *All/Selected IMU's* to report their memory usage. Replies will be reported in the *Communications Panel* as memory status, memory used and the number of tests currently stored; for example "Memory: Ok, Used: 2.0Mb (1.6%), Tests: 1". Clicking [Explore Data Folder] will open a new Windows® Explorer window showing the contents of the current IMU software Data folder.

*Erase IMU Memory*


IMU flash memory must be explicitly erased before it can be re-used. Click [Erase Used Memory] to erase IMU memory currently consumed with logged data. Similarly, clicking [Erase All IMU Memory] will erase all IMU memory whether used or not, and is normally not required.

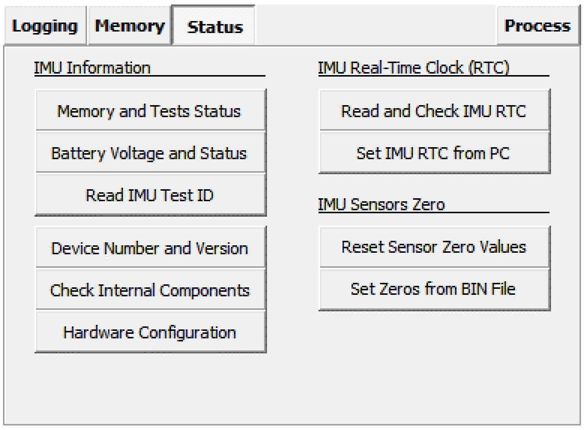
During either erase process the IMU will flash yellow and a progress bar will display the number of IMU's currently being erased, erase progress percentage, and the time taken so far and estimated time to completion (in seconds). Once initiated the erase process occurs autonomously in each IMU which reports when an erase is complete. Ticking *Prompt to Confirm Erase* will display a confirmation warning prompt after an [Erase] button is clicked but before issuing the erase command to *All/Selected IMU's* permitting the command to be cancelled if desired.

*Upload IMU Memory*


Data logged from one or more tests is stored in the IMU memory. All data uploaded from an IMU is saved to a single binary format (*.bin) file from where it is processed to engineering units and saved in comma-separated-variable (CSV) text format (*.csv) files; one CSV file per BIN file test. To upload logged data from *All/Selected IMU's* click the [Upload IMU to BIN File] button. If *Prompt Upload Filename* is ticked, a prompt will be displayed requesting a BIN file name to be used to store data; if data is uploaded from [ALL] in this manner the filename must include the "####" IMU number placeholder characters. Otherwise, the default BIN file name "IMU-####_YYMMDD-HHNNSS.bin" will be used where "####" and "YYYYMMDD-HHNNSS" are placeholder characters which will be replaced with IMU number and the date/time of the first test in the BIN file, respectively. The default file extension for IMU data files is ".bin" (for binary file) and should not be changed. During uploading a progress bar will display the number of IMU's currently being uploaded, upload progress percentage, and the time taken so far and estimated time to completion (in seconds); each IMU will report when uploading is complete. Following upload a BIN filename can be automatically forwarded for processing by ticking *Load BIN File to Process*.

Ticking *Upload All Memory* will upload all, rather than just used, IMU memory and is only required for data recovery in the event of IMU damage.

**Status Commands**




When any IMU's are connected, the [Status] commands group button will be enabled and can be clicked to display miscellaneous IMU status and management commands. Status commands can be sent to *All/Selected IMU's*.

*IMU Information*

Buttons under the IMU Information heading command *All/Selected IMU's* to report their status. Commands, a typical IMU reply and description are:

[Memory and Tests Status].....Memory: Ok, Used: 1.0Mb (0.8%), Tests: 1
The number, and amount of memory consumed by, tests currently in IMU memory.

[Battery Voltage and Status] ..Battery 4.22V, Charging On (Capacity ~100%)
Current IMU battery voltage (usable > 3.5V) and an estimate of its capacity.

[Read IMU Test ID]................IMU Test ID 0
Current IMU *Test Parameter* value.

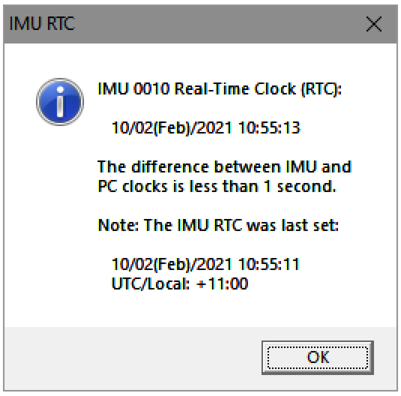
[Device Number and Version] .0011, PCB v03.07.02, Code v03.07.02 [COM14]
IMU device number, hardware and firmware version numbers, and its current (USB Serial Device) COM port number.

[Check Internal Components] .X1 Ok, XG2 Ok, ADc Ok, RTC Ok
Self-reported status of inertial sensors (X1 and X2/G2), analog-to-digital (ADc) converter (for analog input) and real-time-clock (RTC) IC's.

[Hardware Configuration] .......(as follows)

IMU factory hardware configuration: whether external port UART (default) or I²C, and whether +/- analog inputs are individually connected to IMU ground, to 3.3V, or configured to support quarter or half (strain) bridge inputs; default differential-input/full-bridge.

*IMU Real-Time-Clock (RTC)*

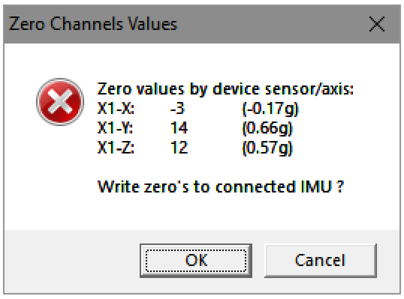



Buttons under the IMU Real-Time Clock (RTC) heading read or set the IMU's RTC. Click [Read and Check IMU RTC] to display a prompt with the IMU's current RTC value and whether it is within 1 second of the PC's clock. If it is the prompt can simply be closed; press [Ok]. If not, the option is given to set the IMU RTC from the PC; click [Yes] or [No]. If [Yes] is chosen, the IMU software will wait for the next PC second to occur then update the IMU's RTC.

Clicking [Set IMU RTC from PC] will immediately update the IMU's RTC as described above. Recommendation: Prior to commencing a logging session set [ALL] IMU RTC's. This will synchronise all connected IMU's RTC with the PC clock as a common datum.

*IMU Sensors Zero*

Buttons under the IMU Sensors Zero perform calibration "zeroing" functions related to the IMU's inertial sensors axis and analog input channels. Zero values, a sensors output when the physical parameter it measures is deemed to be in a zero state, for each channel are stored in an IMU and initially set during factory calibration. To reset zero values (to zero) those inertial sensor axes and the analog input currently configured for logging, click [Reset Sensor Zero Values].




Channel zero values stored in an IMU can be updated based on the average reading for a channel recorded in a BIN file, click [Set Zeros from BIN File]. To do this, first make a recording with the desired channels to be updated configured for logging (*§ Sensor Channels Configuration*) and upload the recording to a BIN file. Then click [Set Zeros from BIN File] and select the created BIN file. The IMU software will calculate the an average for each channel in the BIN file and display these values by the channel output and equivalent engineering units value. To write and update the IMU using the displayed zero values click [Ok], else [Cancel] the operation.

## Processing BIN and CSV Files

Data logged from one or more tests can be stored in the IMU memory. All data uploaded from an IMU is saved to a single binary format BIN (*.bin) file which must be converted to engineering units before further use. The output of conversion is saved in a comma-separated-variable (CSV) text format (*.csv) files; one CSV file per test contained in the BIN file. Further processing and rudimentary plotting of the CSV files can also be performed.

*CSV Files and Format*

The default BIN file name is "IMU-####_YYMMDD-HHNNSS.bin" where "####" and "YYYMMDD-HHNNSS" are placeholders for the IMU number and the date/time of the first test in the BIN file, respectively. The CSV filename is inherited from the source BIN filename appended with the number (incremented from 1) and time of the test in the BIN file with a "_IMU.csv" file extension. For example, processing a BIN file (recorded using IMU 0010 on 10th February 2021 at 12:57:07) containing 4 tests (recorded at 12:57:07, 17:04:12, 12:04:46 and 17:05:16 respectively) would create 4 CSV files:

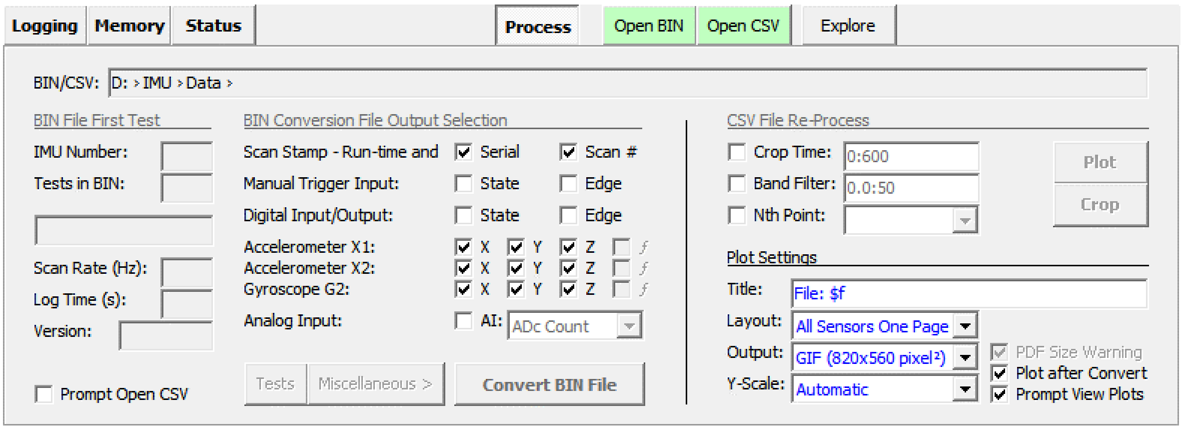
IMU-0010_210210-125707.bin ➔ IMU-0010_210210-125707(Test1_125707)_IMU.csv
➔ IMU-0010_210210-125707(Test2_170412)_IMU.csv
➔ IMU-0010_210210-125707(Test3_170446)_IMU.csv
➔ IMU-0010_210210-125707(Test4_170516)_IMU.csv

The contents of a typical CSV file is illustrated with the following file fragment, with data shown in columns for clarity.

```
' Device: 0010; Hardware: v03.07.02; Firmware: v03.07.02
' Test ID: 0
' Run Started: 10/02(Feb)/2021 17:04:46
' Scan Freq (Hz): 2000
' Log Time (sec): 10; Delay Time (sec): 15; Clock Adj.: 1.000000
'
' Time,    X1-X,    X1-Y,    X1-Z,    G2-X,     G2-Y,     G2-Z
' (Sec),   (g),     (g),     (g),     (°/sec),  (°/sec),  (°/sec)
0.0005,    -0.2,    0.59,    0.68,    1.5,      -0.5,     -0.3
0.001,     -0.2,    0.59,    0.49,    -3.5,     -0.9,     2.7
0.0015,    -0.2,    0.68,    0.39,    1.6,      3.6,      0.3
0.002,     -0.29,   0.78,    0.49,    4.9,      2.2,      1
```

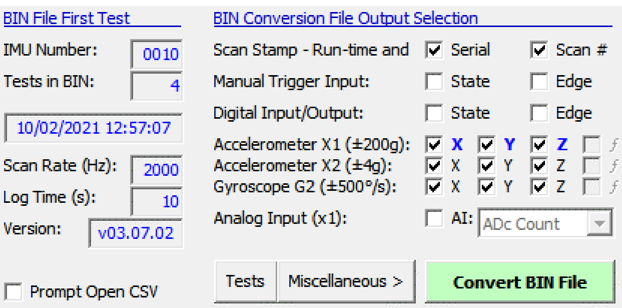
A five line data file header gives the IMU information, the *Test Parameter* value, test initiated date/time, sensors scan rate (Hz), arm delay and logging durations, and any clock adjustment rate. The data file header is followed by one blank line, then the extracted scans data with a separate scan on each line and channel data in comma-delimited columns. Each data column is headed by the channel-axis name and units. By default, each scan is time-stamped with the time (sec) from the start of the test, followed by sensor axis readings in their engineering units.

Processing BIN and CSV files is performed on the *Process* screen accessed by clicking the [Process] command group button which is always enabled.



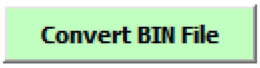


When the *Process* screen is displayed additional buttons are visible to [Open BIN] or [Open CSV] files; click either to browse to, and select the desired BIN or CSV, respectively. The loaded BIN or CSV file name and location will be displayed in the *BIN/CSV:* text box. Clicking [Explore] will open a new Windows® Explorer window showing the contents of the current IMU software Data folder.

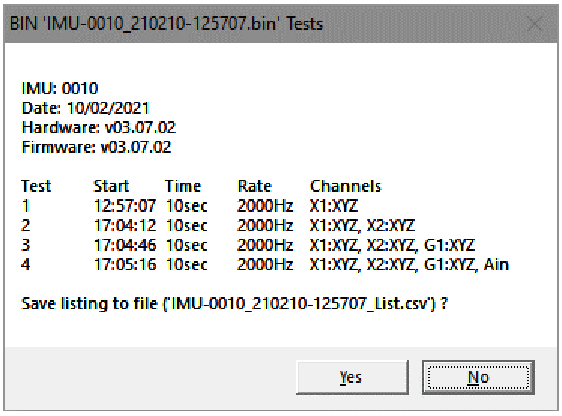



The left side of the *Process* screen contains settings for processing BIN files. When a BIN file is loaded details about the first test in the BIN are displayed under the BIN File First Test heading. This information includes IMU number, number of tests in the BIN, test date/time, scan rate, test duration and BIN file version (inherited from the IMU firmware version).

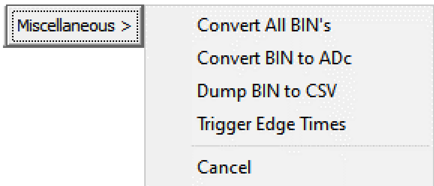
Check-boxes beneath the BIN Conversion File Output heading control what data is exported to the CSV file during conversion. By default, each data scan line in the CSV file is time-stamped with the time (sec) from the start of the test. Time-stamp columns for the equivalent Serial date/time value and scan number can be added if desired by ticking the appropriate checkbox. Similarly, columns showing the state (0/1) and leading edge (0 to 1 transition) of the *Manual Trigger* and GPIO0 digital inputs (always logged) and data channel values for each scan can be added to the CSV file. Note: If a channel was logged in (the first test of) the BIN file, that channels label is shown in blue. For example, channels X1-X, X1-Y and X1-Z were logged during the first test in the example settings screen above (though all inertial channels have been selected for output if present in the BIN file).



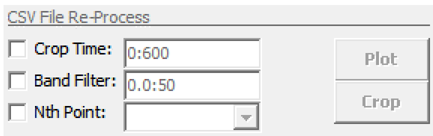

Click [Convert BIN File] to generate CSV file(s) from the loaded BIN file using the selected settings. When conversion is complete, if *Prompt Open CSV* is ticked a prompt will be displayed to open the newly created CSV file in the application registered for that use on the PC (typically Excel®).




Clicking the [Tests] button displays a summary of tests logged in the loaded BIN file.



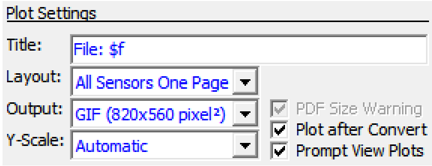

Clicking the [Miscellaneous] button displays a pop-up menu of miscellaneous processing functions. The *Convert All BIN's* menu item will process all BIN files found in the current data folder according to the current settings. This may be convenient for processing BIN files uploaded from multiple IMU's, with the warning that BIN files present from previous uploads will also be (re)processed. The *Convert BIN to ADc* and *Dump BIN to CSV* menu functions are primarily for diagnostic purposes; *Convert BIN to ADc* and will generate a CSV with data expressed in raw sensor output values rather than engineering units, Dump BIN CSV will dump a direct text copy of the BIN file contents to file. The *Trigger Edge Times* menu item will list the time-stamp of any leading edge (0 to 1) transitions of the *Manual Trigger* input found in the BIN file to a text file. This may be useful if the *Manual Trigger* input has been used to flag events of interest during a recording.




The right side of the *Process* screen under the CSV File Re-Process heading contains settings and commands for processing CSV files. The settings, *Crop Time*, *Band Filter* and *Nth Point*, are always enabled because than can be applied to the CSV file created when processing a BIN file. The functions, *Plot* and *Crop*, are only applicable when a CSV file is loaded. Click [Open CSV] to browse to and select a desired CSV. The loaded CSV file name and location will be displayed in the *BIN/CSV:* text box.

When the *Crop Time* check-box is ticked any generated CSV or plot output will be restricted (cropped) to the associated time range; enter minimum and maximum crop run time (sec) delimited by a colon (:). Similarly, a band-pass filter, comprised of single-order low-pass and high-pass filters, can be applied to processed data by ticking *Band Filter* and specifying the high-pass and low-pass filter constants delimited by a colon. Ticking *Nth Point* and selecting either "Excel <= 2003" or "Excel >= 2010" will create a CSV file containing every $N^{th}$ scan line from the BIN file where N is calculated such that, regardless of the number of scan lines in the BIN file, the generated CSV will fully load into Excel® version 2003 or earlier (65536 rows) or Excel® version 2010 or later (1048576 rows). This function may be useful for plotting overviews of complete tests. Click [Plot] (§ Plotting) or [Crop] to plot or crop an existing CSV file according to the current *Crop Time* setting.

*Plotting*




Gnuplot is a public-domain command-line driven graphing utility. If Gnuplot has been installed (*§ Software Installation*) rudimentary plots of test data contained in CSV files can be generated. Various aspects of plots can be controlled using settings below the Plot Settings heading.

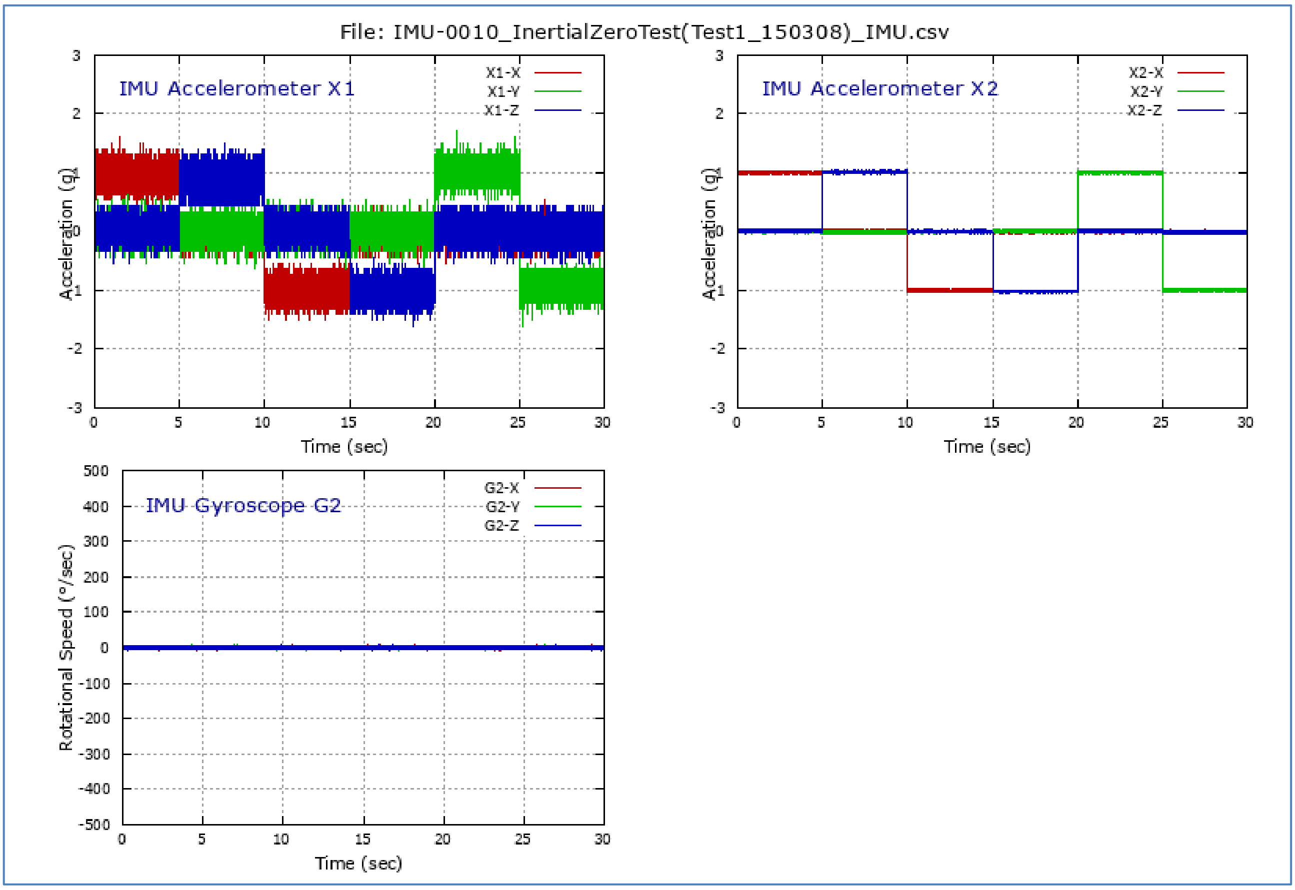
Titles are added to generated plots according to text in the *Title* text-box which may include the following placeholders:

- $f   CSV filename
- $s   Scan frequency of plotted data.

An individual plot for each sensor (X1, X2, G2 and/or AI) contained in the source CSV file is created. The *Layout* setting determines whether plots appear as *All Sensors (on) One Page* or *One Sensor Per Page*. Plots are output as a (820x560 pixel²) GIF picture or (280x190mm², approximately A4) PDF according to the *Output* setting. Note: PDF plots contains all data so may be large and slow to load depending on the number of data points in the source CSV file. Plots show sensor output versus test run time. The range of the sensor output values plotted along the plots y-axis is controlled by the *Y-Scale* setting. Options are *Full-Scale* (X1: ±200g, X2: ±4, 8, 16 or 30g depending on the source BIN file logging configuration, G2: ±500, 1000, 2000 or 4000°/sec depending on logging configuration, AI: ±32000 counts), Automatic where plots are automatically scaled by the minimum and maximum respective sensor output appearing in the file, or a Calibration scale (X1: ±3g, X2: ±3g, G2: ±500°/sec, AI: ±2000counts).

If *PDF* type *Output* is selected and the *PDF Size Warning* check-box is ticked a warning about the time required to generate, and potential PDF size is displayed each time a plot is about to be created. Ticking *Plot after Convert* will automatically plot data contained in a newly CSV generated CSV created by converting a BIN file. Each time a plot is generated, if *Prompt View Plots* is ticked a prompt will be displayed to open the newly created plot in the application registered to view GIF's or PDF's as appropriate.

Following is an example GIF plot of all inertial sensors on one page (during a Inertial Zeroing test).



# Addendum

*IMU USB-C Port Pinouts*

The IMU USB-C receptacle pins, A1 to A12 and B1 to B12, a recommended user-configurable (solder tab) USB-C plug pins, C1 to C9 and D1 to D8, and IMU proprietary pin functions (white background) are given in the following table. Pins GND, VBUS, D+ and D- are standard USB 2.0 pins.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C9/D8 | C1 | C2 | D5 | C3 | C4 | C5 | C6 | D5 | C7 | C8 | C9/D8 |
| GND | GPIO0 | 3.3V | VBUS | GPIO2 | D+ | D- | SCLK | VBUS | MOSI | MISO | GND |
| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 |
| | | | | | | | | | | | |
| B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 |
| GND | AI+ | GPIO1 | VBUS | Vbatt | D- | D+ | TRIGR | VBUS | Reset | AI - | GND |
| C9/D8 | D7 | D6 | D5 | D4 | | | D3 | D5 | D2 | D1 | C9/D8 |

Note: Factory 10nF capacitor between Vbus D5 and Gnd C9/D8

IMU proprietary pin functions are:

| IMU Pin Function | IMU Pin | Plug Pin | Description |
|---|---|---|---|
| GND | A1,A12 | C9 | IMU/USB power ground |
| GPIO0 | A2 | C1 | [1] GPIO0, (default) UART Tx, $I^2C$ SCL |
| 3.3V | A3 | C2 | [2] IMU regulated 3.3V power (IMU internal power, **unfused**) |
| GPIO2 | A5 | C3 | GPIO2, external SPI protocol CS |
| SCLK | A8 | C6 | [3] SPI protocol SCLK (IMU internal bus) |
| MOSI | A10 | C7 | [3] SPI protocol MOSI (IMU internal bus) |
| MISO | A11 | C8 | [3] SPI protocol MISO (IMU internal bus) |
| GND | B1,B12 | D8 | IMU/USB ground |
| AI - | B2 | D1 | [4] Analog input negative |
| Reset | B3 | D2 | IMU CPU Reset – **do not connect** |
| TRIGR | B5 | D3 | 5 User manual trigger input, blue LED – active high |
| Vbatt | B8 | D4 | [2] IMU battery power (**unfused**) |
| GPIO1 | B10 | D6 | [1] GPIO1, (default) UART Rx, $I^2C$ SDA |
| AI + | B11 | D7 | [4] Analog input positive |

Notes:

[1] GPIO0 and GPIO1 are general-purpose digital input/output points (GPIO) which are, by default, connected to the IMU CPU's hardware UART interface. These can be factory altered to the IMU CPU's hardware $I^2C$ interface.

[2] 3.3V and Vbatt are connected to the IMU's internal power supply. These may be used for external sensor power supply but are unfused and should be used with care.

[3] SPI protocol pins are shared with the IMU's internal communications bus.

[4] By default AI- and AI+ are a differential analog input pair. These can be factory altered to be individually connected to IMU ground, to IMU internal 3.3V, or configured to support quarter or half (strain) bridge inputs (full-bride supported by default).

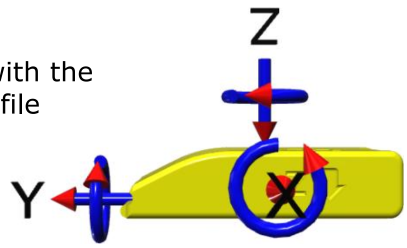
[5] The IMU user manual (logging) trigger input is also connected to the IMU's blue LED, active high, which can be used for user visual annunciation.

*Engineering Units Conversion*

Individual sensor/axis coefficients convert a sensors digital-output "Count" value to an equivalent engineering units value according to the equation:

Engineering Units = Span x (Count - Zero)

Sensor "Zero" values, a sensors output when the physical parameter it measures is deemed to be in a zero state, for each channel are stored in an IMU and initially set during factory calibration. Changing IMU sensor Zero values is described in *§ IMU Sensors Zero*.




Inertial sensor Zero values can be checked at any time by recording a test with the IMU stationary on a horizontal surface and checking the resulting converted file output, noting that in this position the inertial acceleration Z-axis is subject to Earth's -1g gravity.

The default "Span" coefficients for accelerometers and gyroscopes are derived from nominal factory sensitivities of these sensors. These values, and their dynamic range, for IMU sensors are:

| Sensor | Type | Units | Range | Span |
|---|---|---|---|---|
| X1 | Accelerometer | g | ±200 | 4.8780E-2 |
| X2 | Accelerometer | g | ±4<br>±8<br>±16<br>±30 | 1.2207E-4<br>2.4414E-4<br>4.8828E-4<br>9.7656E-4 |
| G2 | Gyroscope | º/sec | ±500<br>±1000<br>±2000<br>±4000 | 1.5267E-2<br>3.0488E-2<br>6.0976E-2<br>1.2195E-1 |
| AI | Analog Input | Count<br>Volt[1] | ±32,365<br>0.0-Vref | 1<br>GainxVref/32365 |

[1] Vref = (factory) IMU reference voltage (typically 3.3V)