VIPS/Airpixel output format and advanced configuration options

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# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision | Date | Change notes | Initials |
| 1 | 01/01/2023 | First Issue | AA |
| 1.1 | 23/04/2023 | Addition of Quaternions and Basic VCU Status Parameters | JB |
| 1.2 | 01/06/2023 | BREAKING CHANGE: Update to FIZ Format to add support for calibrated and uncalibrated lenses, as well as increase precision on Zoom parameter | JB |
| 1.3 | 01/06/2023 | Removed RS232 Title header and added Fizbox/VCU description | JB |
| 1.4 | 01/09/2024 | Undo breaking change from 2023, add new message field to support improved FIZ format, Clarify Airpixel sections, added KF status description | JB |

# Output formats

VIPS outputs data natively via RS232 (as well as CAN, which is outside the scope of this document). The default rate is at 115200 baud, 8Bit, No Parity, 1 Stop Bit, however 460800 is also available in special modes. Talk to Racelogic before considering this.  
  
With the use of additional Hardware (such as a Fizbox or VCU), the same format message can be output over Ethernet via UDP broadcast. If output over Ethernet, the same header bytes and checksum will be included in the data portion of the UDP Packet.

## Racelogic/Airpixel Binary output format



### Introduction

The Racelogic binary format output from VIPS/Airpixel is intended to provide a configurable output that can be set to only output the information of interest. With VIPS, the format of this message will usually be set from within the VIPS site setup software. Section 3.1 gives details of how to manually configure this option if you wish to force a specific message structure.

When connected to a Fizbox/VCU, Airpixel XT also outputs in this format, which is now the unified format for all Airpixel Output. Throughout this document, references to ‘VIPS’ refer to the indoor tracking solution, and references to ‘Airpixel XT’ refer to the outdoor GNSS tracking solution.

The general message structure is:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Header | Message length | Options mask | Time | Location | Optional fields | Checksum |
| 2 bytes | 2 bytes | 4 bytes | 4 bytes | 20 bytes | Variable length | 2 bytes |

All multi-byte values are sent in little endian order (least significant byte first).

### Header

This is a fixed 2 byte pattern of 0x24 followed by 0xD9

### Message length

This is a 16 bit unsigned integer containing the length of the entire message including header bytes and checksum. This allows the message checksum to be verified even if the meaning of some of the options mask bits are unknown.

***Note:*** *Parsers should use this length to calculate the checksum without needing to know all future field options. This makes future version of the protocol backwards compatible, by only parsing the sections that are known at the time, and support for new sections can be added later if needed.*

### Options mask

This is a 32 bit long bit field, each bit indicates whether a specific data field is present in the output message or not. The enabled data fields will always be in the order of least significant bit to most significant bit.

Items in red are automotive specific

Items in Blue are Airpixel specific, and require the use of additional hardware, such as **VCU** or **Fizbox**.

Items in Green are only applicable when used with an outdoor system, such as **Airpixel XT**

Table 1 VIPS output option mask values

|  |  |  |  |
| --- | --- | --- | --- |
| Bit | Name | Usage | Size increase |
| 0 (0x0000\_0001) | GLOBAL | If set position and velocity are in global coordinates. If clear they are in local coordinates. | None |
| 1 (0x0000\_0002) | STATUS | Output basic status information | 4 |
| 2 (0x0000\_0004) | ORIENTATION | Output orientation information | 12 |
| 3 (0x0000\_0008) | VELOCITY | Output velocity information | 8 |
| 4 (0x0000\_0010) | VERT-VELOCITY | Output vertical velocity | 4 |
| 5 (0x0000\_0020) | UNCERTAINTY | Output detailed uncertainty values for all enabled outputs | 12 + 12 if ORIENTATION + 12 if VELOCITY |
| 6 (0x0000\_0040) | ACCURACY | Output basic output accuracy metric and rover ID | 4 |
| 7 (0x0000\_0080) | Reserved1 | Used for Racelogic diagnostics. | 24 |
| 8 (0x0000\_0100) | Reserved2 | Used for Racelogic diagnostics. | 24 |
| 9 (0x0000\_0200) | UNIT\_ID | Rover unit information | 4 |
| 10 (0x0000\_0400) | FIZ\_DATA | Output Basic FIZ data | 8 |
| 11 (0x0000\_0800) | ORIGIN | Output site origin information | 24 |
| 12 (0x0000\_1000) | BEACON\_USED | Beacons used for calculations | 12 |
| 13 (0x0000\_2000) | VCU\_STATUS | Output VCU Status | 4 |
| 14 (0x0000\_4000) | QUATERNION | Output Kalman filter orientation in Quaternions | 16 |
| 15 (0x0000\_8000) | FIZ\_EXTENDED | Output Extended FIZ data | 12 |
| 16-31 | Reserved |  |  |

### Details of output fields

Items in red are automotive specific

Items in Blue are Airpixel specific, and require the use of additional hardware, such as **VCU** or **Fizbox**.

Items in Green are only applicable when used with an outdoor system, such as **Airpixel XT**

Table 2 VIPS Output field details

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Size** | **Format** | **Notes** | **Included if** |
| Header 1 | 1 | uint8\_t | 0x24 | Always |
| Header 2 | 1 | uint8\_t | 0xd9 |
| Length | 2 | uint16\_t | Min 34. Length is full packet including header and checksum. |
| Mask | 4 | uint32\_t | Sets which fields are included in message. See options mask section for details |
| Time | 4 | uint32\_t | Time since midnight UTC in ms. |
| Latitude / X location | 8 | 64 bit double precision float | If GLOBAL bit is set in options mask then these fields contain the Latitude and Longitude in degrees and height above the ellipsoid in meters to WGS 84.  If the GLOBAL bit is clear then they contain the location in meters to the local grid. |
| Longitude / Y location | 8 |
| Altitude / Z location | 4 | 32 bit float |
| Beacon count | 1 | uint8\_t | Number of beacons/sats used in position calculation | Mask bit STATUS set |
| Solution type | 1 | uint8\_t | 1 = 2D/3D Fix: Standard GNSS positioning.  2 = DGNSS: Improved accuracy with corrections, generally less than 1 meter.  3 = RTKFloat: Decimetre-to-meter accuracy while attempting to achieve RTK fixed.  4 = RTK Fixed: High-precision positioning with 2 cm accuracy.  6 = IMU Coast: Positioning using IMU when GNSS is unavailable, accuracy degrades over time  32 = VIPS (UWB): Tracking with 2cm accuracy indoors |
| KFStatus | 2 | uint16\_t | Kalman Filter status indication (See 2.1.6 Kalman Filter Status), key signal of system status required to understand usage. |
| Roll | 4 | 32 bit float | Roll angle in degrees. | Mask bit ORIENTATION set |
| Pitch | 4 | 32 bit float | Pitch angle in degrees. |
| Yaw | 4 | 32 bit float | Yaw/Heading angle in degrees. (3) |
| Speed / Vx | 4 | 32 bit float | If GLOBAL bit is set in options mask then horizontal speed in km/h. Otherwise velocity in the X direction in m/s | Mask bit VELOCITY |
| Heading / Vy | 4 | 32 bit float | If GLOBAL bit is set in options mask then compass heading in degrees. Otherwise velocity in the Y direction in m/s |
| Vertical velocity | 4 | 32 bit float | Vertical velocity (+ = up) in m/s Requires Kalman filter to be running. | Mask bit VERT-VELOCITY |
| Position uncertainty | 12 | 3x IEEE 32 bit float | X,Y,Z standard deviation (m) | Mask bit UNCERTAINTY set |
| Orientation uncertainty | 12 | 3x IEEE 32 bit float | Roll, Pitch, Yaw standard deviations (deg/s) | Mask bits UNCERTAINTY && ORIENTATION set |
| Velocity uncertainty | 12 | 3x IEEE 32 bit float | X,Y,Z Velocity standard deviations in m/s | Mask bits UNCERTAINTY && VELOCITY set |
| Position accuracy | 1 | uint8\_t | Position residual in meters \* 20. | Mask bit ACCURACY set |
| Reliability flags | 1 | uint8\_t | See Table 3 below |
| Velocity accuracy | 1 | uint8\_t | Velocity residual in meters \* 10  Undefined if VELOCITY not output |
| Rover/Camera ID | 1 | uint8\_t | Rover ID number (1)  In Airpixel, this represents Camera ID (1) |
| Reserved1 | 24 |  | Racelogic debug outputs | Reserved1 set |
| Reserved2 | 24 |  | Racelogic debug outputs | Reserved2 set |
| Unit info | 3 | uint24\_t | Unit unique radio ID number | Bit UNIT\_INFO set |
| Rover ID | 1 | uint8\_t | Rover ID number  In Airpixel, this represents Camera ID |
| Focus Distance | 4 | uint32\_t | Focus distance in mm or raw encoder count (lens dependant) (2) (4) | Bit FIZ\_DATA set (4) |
| Iris | 2 | uint16\_t | Iris aperture in 100ths of a T-Stop or raw encoder count (lens dependant) (2) (4) |
| Focus length (zoom) | 2 | uint16\_t | Focal length in mm or raw encoder count (lens dependant) (2) (4) |
| Origin LLA | 20 | 2x IEEE 64 bit double + 1 x IEEE 32 bit float | Site origin location in degrees latitude, degrees longitude and meters. | Bit ORIGIN set |
| Origin rotation | 4 | IEEE 32 bit float | Site rotation angle in degrees. |
| Beacons used | 12 | 12x uint8\_t | List of beacon IDs (VIPS) used in position calculation in no particular order. Always padded to 12 values with 0’s for unused beacons. | Bit BEACON\_USED set |
| Frame rate | 1 | uint8\_t enum | Values of 0 - 11 indicate frame rates of None, 23.976, 24, 25, 29.97, 29.97DF, 30, 48, 50, 59.94, 59.94DF, and 60 respectively.  If zero/none, no sync detected  If ‘0xFE/254’, Unknown Sync Detected  If 0xFF/255, Free Running at 100hz | Bit VCU\_STATUS set(2) |
| Lens Type | 1 | uint8\_t enum | Values are: None (0), Preston (1), Fuji (2), Canon (3), Arri (Pending Support, 4), Zeiss (Pending Support, 5), with others potentially added later. If zero/none, no Lens detected. |
| VCU Status | 1 | uint8\_t  Bitflag Field | 1: Using Timecode  2: 0=VIPS Data, 1=GPS Data (outdoor Airpixel)  4: Power Source (0=VIN, 1=PoE)  8: Running on Backup-Battery Warning  16: Backup-Battery Charging  32: Logging Active  64: SD Card over 80% Full  128: RESERVED |
| Reserved | 1 | uint8\_t | RESERVED |
| Orientation in quaternions | 16 | 4 x IEEE 32 bit float | Orientation as a Quaternion x, i, j & k values | Bit QUATERNION set |
| Focus Distance | 4 | uint32\_t | Bit 31 set:   * Focus distance in 100th/s mm   Bit 31 unset:   * Raw encoder count | Bit FIZ\_EXTENDED set (2) |
| Iris | 4 | uint32\_t | Bit 31 set:   * Iris aperture in 100th/s of a T-Stop   Bit 31 unset:   * Raw encoder count |
| Focal Length (Zoom) | 4 | uint32\_t | Bit 31 set:   * Focal length (zoom) in 100th/s of a mm   Bit 31 unset:   * Raw encoder count   Bits 30-24 (7 bits):   * Telephoto Multiplier |
| Checksum | 2 | 2x uint8\_t | Standard VBOX checksum. Header and length included. (See Checksum) | Always |

Notes:

1) Rover ID will be 254 for the first rover, 253 for the second etc…  
 - In Airpixel this will be converted to a standard camera number by the VCU/Fizbox (1, 2 ,3 etc) if set within settings

2) FIZ related data cannot currently be output directly from the VIPS unit, it is included in the protocol to allow external modules to add the data to the packet (such as Fizbox or VCU)

3) Orientation-Yaw is the raw Kalman filer output, when outputting global coordinates (Lat, Long) it is not rotated to allow for the site rotation. If a correctly rotated value is needed use the heading field from the velocity block.

4) ‘FIZ\_DATA’ field will slowly be deprecated in favour of ‘FIZ\_EXTENDED’ field, however both are required to be supported in Virtual Production until at least 2026.

Table 3 Reliability Flag values

|  |  |  |
| --- | --- | --- |
| Bit | Usage | Description |
| 0 (0x01) | Outside beacons | Set if the calculated position is outside a bounding box defined by the beacon locations |
| 1 (0x02) | Insufficient beacons | Set if the number of beacons is below the minimum |
| 2-6 | Reserved |  |
| 7 (0x80) | Do not use | Set if the position is outside the bounding box or had insufficient beacons. Assuming beacon count is not zero the output will still be a best estimate available but the user should switch to alternative positioning systems if available. |

### Kalman Filter Status

The KF (Kalman Filter) Status is a 16-bit value representing the state of the Kalman Filter. While some bits in this value may change frequently to indicate data updates, the overall status functions like a state-machine, determined by specific combinations of bits. During start-up, certain bits that are typically masked out (using the mask **0xE634**) are visible and can be used to determine the initial state. Once the system is operational, these bits are masked out, and the Kalman Filter transitions into a stable operating mode.

**Start-up Specific States:**

* **0x0040**: **Reset / Startup** – The Kalman Filter is initializing or resetting. This status is only visible during the early stages of system start-up and does not appear during normal operation.
* **0x007E**: **Disabled** – The Kalman Filter is disabled. No Orientation data will be available.
* **0x007F**: **Looking for IMU** – The system is searching for input from the IMU (Inertial Measurement Unit). This state occurs during start-up but may indicate an issue with IMU connectivity if it persists.

**Operational States:**

The following statuses are determined by the bitfield after masking out frequently changing bits using the mask 0xE634. These states are more stable and indicate the system’s operational status.

* **0x0014**: **Waiting for Position** – The system is waiting for external position data, either from VIPS or GNSS. This is normal during start-up, but may indicate a fault if this status persists.
* **0x0004 or 0x0024**: **No IMU Data** – The Kalman Filter is not receiving IMU data, which may occur during startup, but likely indicates a fault if this status persists.
* **0x0034**: **Static Initialisation** – The Kalman Filter is initialising while the system is stationary. This typically takes 30 seconds, during which time the device must not be moved.
* **0x0234**: **Ready for Motion** – The system has completed the stationary period and is ready to be moved in a forward’s direction.
* **0x2234 or 0x4234**: **KF Starting** – The initialisation is complete, and the filter is transitioning into running mode. Continue moving until the system transitions into ‘running’ mode
* **0x8034**: **Running** – The Kalman Filter is fully operational and processing data correctly. System will remain in ‘running’ state unless it detects it has reached the stationary threshold for ‘ZUPT’ condition (see below).
* **0x0400**: **ZUPT Active** – Zero velocity updates (ZUPT) are being used to stabilize the system's position and orientation. This only occurs when the system has determined it is stationary.

For any other values, the status is considered **Unknown** as it doesn’t match a known state.

**Note**: Bits excluded by the mask (**0xE634**) change frequently during operation and do not affect the overall state. These bits primarily indicate that data is being updated but should be ignored for determining the system’s core status.

### Checksum

The checksum uses the standard Racelogic VBOX CRC calculation. This is a standard CRC-16 routine with an initial value of 0 and a polynomial of 0x1021. For legacy reasons this is sent in big endian format and so should be treated as two uint8\_t values rather than a single uint16\_t value.

### Example data

**24 D9** 36 00 **46 00 00 00** 50 5F 00 00 **D9 CE F7 53 E3 A5 0B 40** 58 39 B4 C8 76 BE F3 BF **66 66 E6 3F** 0C **20** 35 02 **CD CC 8C BF** 00 00 C0 3F **CD 4C 0C 43** 00 00 00 **FE** 2F 25

24 D9 – Header bytes

36 00 – Message length = 0x0036 = 54 bytes

46 00 00 00 – Options mask = 0x0000 0046 = Accuracy, orientation, status.

50 5F 00 00 – Time = 0x00005F50 = 24,400 = 24 seconds, 400 ms after midnight.

D9 CE F7 53 E3 A5 0B 40 – X = 3.456000

58 39 B4 C8 76 BE F3 BF – Y = -1.234000

66 66 E6 3F – Z = 1.800000

0C – Beacons = 12

20 – Solution type = 32 (VIPS only)

35 02 – Kalman filter status = 0x0235, static initialisation

CD CC 8C BF – Roll = -1.100000

00 00 C0 3F – Pitch =1.500000

CD 4C 0C 43- Yaw = 140.300003

00 00 00 – Accuracy values

FE – Rover ID = 254 (rover 1)

2F 25 – Checksum

## NMEA output mode

In NMEA output mode the "BinaryOutput" entry in the setup JSON file is used to select which standard NMEA messages will be output. This is intended for Automotive use only.

The supported options are:

|  |  |  |
| --- | --- | --- |
| Bit | Name | Usage |
| 0 (0x0000\_0001) | GGA Enable | If set the $GPGGA message will be output |
| 1 (0x0000\_0002) | RMC Enable | If set the $GPRMC message will be output |

NMEA messages give a far lower data density than Racelogic binary messages and so only one message can be output at 100Hz. If more messages are enabled than is possible with the user selected output rate then the output rate will automatically be decreased to the point where the messages can be reliably output.

# Operation options

There are a number of options to control how the VIPS system will operate. Normally these can be set from the VIPS site setup software but they can also be set directly. See section 3.2 for details of how to view or set this value manually.

The options value is in the form of a series of binary bit fields. These values should be added together to give the final options value

|  |  |
| --- | --- |
| Bit | Name |
| 0 (0x0000\_0001) | Enable blocked beacon detection |
| 1-2 (0x0000\_0006) | Elevation correction mode |
| 3 (0x0000\_0008) | Disable low pass filter |
| 4 (0x0000\_0010) | Force VIPS mode |
| 5 (0x0000\_0020) | Disable fine grain sync |
| 8 (0x0000\_0100) | Studio LED mode |
| 9 (0x0000\_0200) | Disable single sided fallback |
| 16-19 (0x000F\_0000) | Geofence size |

## Blocked beacon detection

This option requires that either the output rate is set to 20 Hz or less or the Kalman filter is enabled.

In this mode the system will attempt to detect and exclude beacons that are giving unreliable ranges, normally this would be caused by some form of obstruction between the rover and the beacons.

Due to the risk of false detection and failed detections this option is intended for unforeseeable obstructions such as people or mobile equipment. Enabling it when not required can in some situations decrease system performance. For static obstructions it is recommended to instead edit the ping table in order to avoid attempting to use known bad beacons.

## Elevation correction

This 2 bit option allows different methods to compensate for variations seen when passing directly underneath or close to a beacon. If the beacons are all to the side of your operating area this option can be left off. The available options are:

|  |  |  |
| --- | --- | --- |
| Option | Value in options field | Usage |
| 0 | 0 | Off. |
| 1 | 0x02 | Small room – Best for an office type environment |
| 2 | 0x04 | Large room – A studio or small test area where beacons will typically be around 3 meters from the floor. |
| 3 | 0x06 | Very large room – A large area where beacons will be 5 meters or more off the floor. |

## Disable low pass filter

When operating without a Kalman filter VIPS defaults to passing the output position and velocity through a 5Hz Butterworth low pass filter. This option can be used to disable that filter if required.

## Force VIPS mode

Only applicable when in VB3i indoor/outdoor or ADMA mode. This option forces the system to only ever use VIPS even if set to indoor/outdoor mode. This should be used when GPS is only being used as a time source and never used for positioning.

## Disable fine grain sync

Only applicable when in multi-rover mode. Normally when running in multi-rover mode the system will attempt to synchronise the internal clocks between rovers. If the PPS is from a reliable external source (e.g. a VB3i in indoor/outdoor mode) then it is better to disable this and trust the PPS for cross unit synchronisation.

## Studio LED mode

Beacon only. When enabled the beacon will disable its LED 30 seconds after first seeing a rover. The LED will then remain off until the unit is next reset or power cycled.

## Single Sided Fallback.

Required Beacon F/W 1.0.2, Rover radio F/W 1.2.14, Wearable MM F/W 1.????.  
Under normal operation VIPS uses double sided two way ranging. While this provides the best possible accuracy it requires 4 radio messages to produce a range, if any of these 4 are lost due to interference then the range measurement fails. Single sided ranging allows the rover to calculate a range from just the first two of these messages.   
When enabled if the system has insufficient information to calculate a double sided range it will fall back to a single sided calculation. This will increase the number of measurements available to the position calculation engine in the event of intermittent jamming and multi-rover systems. However this method of ranging can result in a slight increase in measurement noise in some situations and so may not be suitable for every application.

Note that for Radio FW 1.2.14-1.2.15 this bit was used to enable single sided. From 1.2.16 this was swapped to single sided being enabled as default and this bit being used to disable it.

## GeoFence Size

Requires position engine 1.5.48 or later.

As default VIPS implements a basic geofence around the covered area. If the rover passes outside of this fence then the output is flagged as do not use. This will impact the reliability flags section of the serial message, the CAN output and the VB3i when in indoor/outdoor mode. Note, other than a VB3i in indoor/outdoor mode this will not have any addition impact on the system operation, it will still attempt to operate as normal. This is purely intended as an indicator to the user equipment that the rover is leaving the covered area.  
This fence defaults to 10m outside of the beacon covered area.  
The size is set as 10 – the value of this 4 bit field allowing the user to reduce the size of this fence by up to 15 meters and thus placing it inside the covered area if desired.

In all cases a 1 meter hysteresis is applied, the rover must move 1 meter further in to the site to clear the flag.

# Manual configuration of VIPS options

Most VIPS options can be configured from within the VIPS Site setup software. However some newer or less common combinations and options may not be fully supported by the software. It is possible to manually force a specific configuration by editing the setup JSON file in a text editor. When this modified JSON file is loading into site setup the user set values will be maintained unless the configuration is later changed in the user interface.

There are two different configuration options that may be modified by the user, the output format and the operating mode options. When editing these values ensure that only the required value is changed and that no other file contents, including commas at the ends of lines, are changed.

## Output format

This setting is found under “BinaryOutput” in the JSON file. It controls the desired VIPS binary or NMEA output options.

In binary output mode the value set here will be used as the requested options mask as detailed in section 1.1. The options value in the output message will normally be the same as the option set here unless an invalid combination of options has been selected. For example orientation channels will only be output if the Kalman filter is also enabled. The user should always parse a message based on the options field it contains not the value requested in the JSON file.

In NMEA mode this value sets which NMEA messages are output as detailed in section 1.2

## Operating Options

This setting controls a number of options used to control the operation of the VIPS system. As with the output format settings these can normally be set from the UI but the selection can also be manually forced by changing the .json file.

This value can be found in the JSON file under “Options” within the "SystemConfiguration" section of the file.

Details of the available options are given in section 2.