

VEET 2.1 Data Interpretation Guide

Introduction

This guide provides keys and examples to help researchers understand the values of the lines of data in the Visual Environment Evaluation Tool (VEET) sensor file.

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Note on Data Firmware Versions

The format of the VEET data file (sensor_data.csv) was updated with Firmware Version FW2.1.3. This latest version includes changes to the Information (INF), Spectral Sensor (PHO) and Ambient Light Sensor (ALS) data lines. Please see [Appendix: Changes in VEET Firmware](#) for keys and examples of the VEET data lines in this older format.

You can find your data's Firmware version in the Information (INF) line, as shown in **bold** below:

```
1753219398,INF,VEET,25060547,FW2.2.3 Jul 16 2025
```

If there is an already existing sensor_data.csv file on the VEET, the existing data file won't be updated or deleted when you update the device to FW2.1.3 or later. However, all new data is logged in the updated data format. To avoid logging mixed-format data, delete the old sensor_data.csv file from the device after the update.

- Waking from Deep Sleep
- Manually restarted, such as for a configuration update
- Undergoes a firmware update

Organization of Data in an Information Line

[time_stamp], INF, [product_name], [serial_number], [fw_version], [Researcher_ID], [Participant_ID], [Time_Zone_offset], [IMU_interval], [PHO_interval], [TOF_interval], [ALS_interval], [Temple_config]

Key for Information Line

Item	Detail
time_stamp	The Unix time since 1970-01-01 00:00:00 UTC in seconds. Possible values: 1325376002 to 1893484800+ Data type: uint32
INF	The current line is information data. Only value: INF Data type: string
product_name	The hardware version of the temple arm of the VEET device. Possible values: HW2.x.x, Data type: string
serial_number	The unique identifier of the temple arm of the VEET device. Data type: string
fw_version	The build version of the firmware of the temple arm of the VEET device. Possible values: FW2.x.x Data type: string
Researcher_ID	The identifier of the researcher.
Participant_ID	The identifier of the research participant.
Time_Zone_offset	The time zone from UTC of the temple arm of the VEET device.
IMU_interval	The time between sensor reads in milliseconds.
PHO_interval	The time between sensor reads in milliseconds.
TOF_interval	The time between sensor reads in milliseconds.
ALS_interval	The time between sensor reads in milliseconds.
Temple_Config	Indicates the temple arm is left or right.

Spectral Sensor (PHO)

The Spectral Sensor or PHO line reports the data from the Spectral sensor.

Observations on Spectral Sensor data:

- All counts provided by this sensor are reported in calibrated raw counts. These counts must be further processed to provide useful spectral information. Please see [Appendix: Converting Raw PHO Counts to Basic Counts](#) below.

Organization of Data in a Spectral Sensor Line

[time_stamp],PHO,[Integration],[Gain],[415_nm],[445_nm],[480_nm],[515_nm],[555_nm],[590_nm],[630_nm],[680_nm],[IR],[Dark],[Clear]

Note: The last 11 columns are the raw sensor values.

Key for Spectral Sensor Line

Item	Detail
time_stamp	The Unix time since 1970-01-01 00:00:00 UTC in seconds. Possible values: 1325376002 to 1893484800+ Data type: uint32
PHO	The current line is spectral sensor data. Only value: PHO Data type: string
Integration	The length of time for the measurement by the sensor in milliseconds, currently fixed. Only value: 100 Data type: uint16
Gain	The index of the gain used by the sensor at time of reading. References to a gain table.
415_nm	The response* in raw counts, centered on nominal wavelength of 415nm and bandwidth of 26nm FWHM. Value Range: 0 to 65535, Data type: uint16
445_nm	The response in raw counts, centered on nominal wavelength of 445nm and bandwidth of 30nm FWHM.- Value Range: 0 to 65535, Data type: uint16
480_nm	The response in raw counts, centered on nominal wavelength of 480nm and bandwidth of 36nm FWHM. Value Range: 0 to 65535, Data type: uint16
515_nm	The response in raw counts, centered on nominal wavelength of 515nm and bandwidth of 39nm FWHM. Value Range: 0 to 65535, Data type: uint16
555_nm	The response in raw counts, centered on nominal wavelength of 555nm and bandwidth of 39nm FWHM. Value Range: 0 to 65535, Data type: uint16
590_nm	The response in raw counts, centered on nominal wavelength of 590nm and bandwidth of 40nm FWHM. Value Range: 0 to 65535, Data type: uint16
630_nm	The response in raw counts, centered on nominal wavelength of 630nm and bandwidth of 50nm FWHM. Value Range: 0 to 65535, Data type: uint16
680_nm	The response in raw counts, centered on nominal wavelength of 680nm and bandwidth of 52nm FWHM. Value Range: 0 to 65535, Data type: uint16
IR	The response centered on nominal wavelength of 910nm and bandwidth of 104nm FWHM in raw counts. Value Range: 0 to 65535, Data type: uint16
Dark	The response on the masked channel in raw counts. Used to measure noise

Item	Detail
	level. Value Range: 0 to 65535, Data type: uint16
Clear	The response at full spectrum in raw counts. Value Range: 0 to 65535, Data type: uint16

Inertial Measurement Unit (IMU)

An inertial measurement unit or `IMU` line reports the data from the IMU sensor.

Observations on Inertial Measurement Unit data:

- The IMU is not calibrated:
 - Resting acceleration magnitude won't exactly match local gravity and may differ by up to $\pm 0.2 \text{ m/s}^2$ per manufacturer's datasheet.
 - Resting gyroscope may show noise up to ± 0.5 degrees per second in addition to an offset of 2.5 dps.
- The IMU is housed along the temple arm, thus the acceleration data can be post processed to estimate head tilt.
- Both Acceleration and Gyroscopic data can be used to determine if the device is being worn.
- When the glasses frames are oriented upright and resting on a flat, level surface, the acceleration axis is vertical (Y axis) with an approximate value of -9.8 m/s^2 .
- The temperature reading included in the IMU data line is not calibrated and measures the internal temperature of the device. This temperature lags behind environmental temperature changes. This time delay has not been characterized.

Organization of Data in an Information Line

[time_stamp],IMU,[ax],[ay],[az],[gx],[gy],[gz],[temp]

Key for Inertial Measurement Unit Line

Item	Detail
time_stamp	The Unix time since 1970-01-01 00:00:00 UTC in seconds. Possible values: 1325376002 to 1893484800+ Data type: uint32
IMU	The current line is inertial measurement unit sensor data. Only value: IMU Data type: string
ax	The position of the X-axis accelerometer in meters per second-squared. Possible values: -39.24 to +39.24 (-4g to +4g) , Data type: float
ay	The position of the Y-axis accelerometer in meters per second-squared. Possible values: -39.24 to +39.24 (-4g to +4g) Data type: float
az	The position of the Z-axis accelerometer in meters per second-squared. Possible values: -39.24 to +39.24 (-4g to +4g) Data type: float
gx	The angle of the X-axis gyroscope in degrees per second. Possible values: 0 to

Item	Detail
	2000 Data type: float
gy	The angle of the Y-axis gyroscope in degrees per second. Possible values: 0 to 2000 Data type: float
gz	The angle of the Z-axis gyroscope in degrees per second. Possible values: 0 to 2000 Data type: float
temp	The temperature captured by the IMU sensor in degrees Celsius. Possible values: -41 to +87 Data type: int 16



Orientation of IMU axis

Time of Flight Sensor (ToF)

A time of flight or `TOF` line reports the data from the Time of Flight (ToF) sensor.

Observations on Time of Flight Sensor data:

- The Time of Flight sensor has been validated to not require device-specific calibration.
- When the VEET is fully occluded, the Time of Flight Sensor reads approximately 11mm: the distance from the sensor to the surface of the glass.

Organization of Data in a Time of Flight Sensor line

[time_stamp], [TOF], conf1[0:63], conf2[0:63], dist1[0:63], dist2[0:63]

From the point of view of the research participant looking out, the Time of Flight (TOF) data is organized as an 8x8 array with the first value in the upper right corner (Row 0, Column 7), and the next data value in (Row 0, Column 6). As such, (Row 1, Column 7) is the first data value on the second row. The lower left corner of the array, which contains the last final data value, is (Row 7, Column 0).¹

Key for Time of Flight Sensor Line

Item	Detail
time_stamp	The Unix time since 1970-01-01 00:00:00 UTC in seconds. Possible values: 1325376002 to 1893484800+ Data type: uint32
TOF	The current line is time of flight sensor data. Only value: TOF Data type: string
conf1[0:63]	Object 1 confidence: the signal-to-noise ratio for the 1st object in the zone. Possible values: 0 to 255 Data type: uint8
conf2[0:63]	Object 2 confidence: the signal-to-noise ratio for the 2nd object in the zone. Possible values: 0 to 255 Data type: uint8
dist1[0:63]	The distance to Object 1 in the zone in millimeters. Possible values: 0 to 5000 Data type: uint16
dist2[0:63]	The distance to Object 2 in the zone in millimeters. Possible values: 0 to 5000 Data type: uint16

The Data[0:63] values—meaning, the values for conf1[0:63], conf2[0:63], dist1[0:63], and dist2[0:63]—are organized as a raster scan with [row, column] [0, 7] in the upper right. The orientation is facing away from the sensor (0, 7: upper right; 7, 0: lower left).

Orientation of Time of Flight Sensor

	Column 0	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Row 0	7	6	5	4	3	2	1	0
Row 1	15	14	13	12	11	10	9	8
Row 2	23	22	21	20	19	18	17	16
Row 3	31	30	29	28	27	26	25	24
Row 4	39	38	37	36	35	34	33	32
Row 5	47	46	45	44	43	42	41	40
Row 6	55	54	53	52	51	50	49	48
Row 7	63	62	61	60	59	58	57	56

¹ The original July 23, 2025 publication of the VEET 2.1 Data Interpretation Guide incorrectly states the data on the Time of Flight Sensor line is organized left-to-right.

Illustration of Time of Flight Sensor Data Orientation

	Column 0	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Row 0	7	6	5	4	3	2	1	0
Row 1	15	14	13	12	11	10	9	8
Row 2	23	22	21	20	19	18	17	16
Row 3	31	30	29	28	27	26	25	24
Row 4	39	38	37	36	35	34	33	32
Row 5	47	46	45	44	43	42	41	40
Row 6	55	54	53	52	51	50	49	48
Row 7	63	62	61	60	59	58	57	56

¹ The original July 23, 2025 publication of the VEET 2.1 Data Interpretation Guide incorrectly states the data on the Time of Flight Sensor line is organized left-to-right.

Ambient Light Sensor (ALS)

The light meter or ALS line reports the data from the Ambient Light Sensor.

Observations on Ambient Light Sensor data:

- All counts provided by this sensor are reported in calibrated raw counts. These counts must be further processed to provide useful spectral information. Please see [Appendix: Converting Raw ALS Counts to Basic Counts](#) below.
- Lux values report from 0.001 to 100000+ with no hard upper limit.
- 0 Lux is reported as 0.001 to aid in logarithmic plotting of the data.
- In the event of sensor saturation, which may happen when the sensor is searching for the right gain value, the event is not reported in the Sensor_data.csv file but logged in the log.csv file. It is typical for this sensor to saturate when transitioning from very dark to very bright conditions.
- The device reports flicker up to 7kHz. If the sensor cannot determine a flicker, it reports NAN.

Organization of Data in an Ambient Light Sensor Line

```
[time_stamp],ALS,[Integration],[uvGain],[visGain],[irGain],[uvValue],[visValue],[irValue],[Flicker],[Lux]
```

Key for Ambient Light Sensor Line

Item	Detail
time_stamp	The Unix time since 1970-01-01 00:00:00 UTC in seconds. Possible values: 1325376002 to 1893484800+ Data type: uint32
ALS	The current line is light meter sensor data. Only value: ALS Data type: string
Integration	The length of time for the measurement by the sensor in milliseconds. Analogous to shutter speed. Only value: 100 Data type: uint16
uvGain	The index of the gain used by the UV channel at time of reading. References to a gain table.
visGain	The index of the gain used by the visible channel at time of reading. References to a gain table.
irGain	The index of the gain used by the near IR channel at time of reading. References to a gain table.
uvValue	The response* in raw counts of the UV channel. Possible values: 0 to 1048575 Data type: float
visValue	The response* in raw counts of the visible channel. Possible values: 0 to 1048575 Data type: float
irValue	The response* in raw counts of the near IR channel. Possible values: 0 to 1048575 Data type: float
Flicker	The predominant flicker rate of light during sensor read in hertz. Possible values: 0 to 7000 otherwise NAN

Item	Detail
Lux	The estimated function of visible and IR channels in lux.

Appendix: Converting Raw PHO Counts to Basic Counts

When sensing light spectrum, the PHO sensor self-adjusts to different lighting conditions (e.g. a bright sun-lit day outside vs. a dark room) by becoming more or less sensitive. This is called the “gain.” To account for those changes in sensitivity and compare sensor data points, researchers must account for the gain in their calculations.

In post-processing, raw PHO Counts should be converted to Basic Counts to obtain a standardized value for each wavelength under any lighting condition. To calculate Basic Counts from Raw Counts, you need the Gain Ratio and Integration time (ms). To obtain the Gain Ratio, first find the Gain Index in the PHO sensor line (listed as “Gain” in [Organization of Data in a Spectral Sensor Line](#)). Then, use the Index to find the Gain Ratio in the table below. The PHO Integration Time is currently a fixed value in the VEET.

The formula to calculate Basic Counts is as follows:

$$\text{Basic_Counts} = \text{Raw_Counts} / \text{Gain_Ratio} / \text{Integration_Time}$$

Where Gain_Ratio is referenced in the following table:

PHO Gain Ratios	
Index	Ratio
0.5	0.008
1	0.0016
2	0.032
4	0.065
8	0.125
16	0.25
32	0.5
64	1
128	2
256	3.95
512	7.75

Example:

Raw Count: 4517

Gain Index: 128

Gain Ratio: 2

Integration Time: 100

Formula: $4517 / 2 / 100 = 22.585$ PHO Basic Counts

Appendix: Converting Raw ALS Counts to Basic Counts

When sensing for illuminance, the ALS sensor self-adjusts to different lighting conditions (e.g. a bright sun-lit day outside vs. a dark room) by becoming more or less sensitive. This is called the “gain.” To account for those changes in sensitivity and compare sensor data points, researchers must account for the gain in their calculations by using the following formula.

In post-processing, raw ALS Counts should be converted to Basic Counts to obtain a standardized value for each sensor channel under any lighting condition. To calculate Basic Counts from the channel’s Raw Counts (whether that is from the UV, visible, or IR channels), you need the Gain Ratio and Integration time (ms). To obtain the Gain Ratio, first find the corresponding channel’s Gain Index in the ALS sensor line (listed as “uvGain, visGain, or irGain” in [Organization of Data in a ALS Sensor Line](#)). Then, use the channel’s Gain Index to find the Gain Ratio in the table below. The ALS Integration Time is currently a fixed value in the VEET.

The formula to calculate Basic Counts is as follows:

$$\text{Basic_Counts} = \text{Raw_Counts} / \text{Gain_Ratio} / \text{Integration_Time}$$

Where Gain_Ratio is referenced in the table:

ALS Gain Ratios

Index	Ratio
0.5	0.004013969
1	0.008074283
2	0.015880578
4	0.031525851
8	0.0643915
16	0.125470514
32	0.250626566
64	0.497512438
128	1
256	1.93
512	3.8
1024	7.42
2048	14.06
4096	25.35

Example (using the visible channel):

vis Raw Count: 4517

vis Gain Index: 128

Gain Ratio: 1
Integration Time: 100
4517 / 1 / 100 = 45.17 ALS Basic Counts

Appendix: Changes in VEET Firmware

Firmware version 2.1.3 made several changes to the data format. These changes were implemented for the following reasons:

Changes in Information (INF) Line

- Reduced legacy data and information that is no longer utilized.

Organization of Data in an Information Line (FW2.1.2 and previous)

```
1709249589,INF,VEET_1.5,3G7Z178FCD0011,FW1.49h Feb 13 2024  
17:24:57,abc123,abc123,-8,2000,2000,2000,2000,R,250,1.00,1.00,1.00,1.00,s,mV,ms  
,m/s^2,deg/s,count,#,mm,count,#,Hz
```

Organization of Data in an Information Line (FW2.1.3 and above)

```
1753219398,INF,VEET,25060547,FW2.2.3 Jul 16 2025  
15:41:35,abc123,abc123,-8,2000,2000,2000,2000,L
```

Changes in Spectral Sensor (PHO) Line

- Clear channel reporting changed from ClearL and ClearR to a single aggregated value: Clear. The change simplifies post processing.

Organization of Data in a Spectral Sensor (PHO) Line (FW2.1.2 and previous)

```
1709249595,PHO,50,512,48,135,137,221,239,282,389,262,459,0,901,910
```

Organization of Data in a Spectral Sensor (PHO) Line (FW2.1.3 and above)

```
1741824129,PHO,100,512,10,22,30,44,55,75,92,64,39,0,198
```

Changes in Ambient Light Sensor (ALS) Line

- The way flicker is reported when the sensor is saturated changed to NAN for easier data analysis.

Organization of Data in an Ambient Light Sensor Line (FW2.1.2 and previous)

1706922030,ALS,100,4096,1024,2048,0,0,0,65534,0.0000

Organization of Data in an Ambient Light Sensor Line (FW2.1.3 and above)

1741824153,ALS,100,4096,4096,4096,153,33,638,NAN,0.0000