DK2 Firmware Specification

Nirav Patel

Revision 0.10
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Contents

1   Revision History

Revision	Date	Description
0.1	28-11-2013	Preliminary specification.
0.2	08-12-2013	Add camera feature report.
0.3	11-12-2013	Add display feature report.
0.4	23-12-2013	Add magnetometer and position calibration and LED pattern reports.
0.5	26-12-2013	Add keep alive, manufacturing, and uuid reports.
0.6	30-01-2014	Add temperature report, modify position report.
0.7	13-02-2014	Add gyro offset report.
0.8	18-02-2014	Add normals to position calibration, rename camera to tracking.
0.9	24-02-2014	Add lens distortion report.
0.10	28-04-2014	Add basic EDID information.

2   Introduction

The Rift DK2 is interfaced using USB HID with a 1000 Hz polling rate. The device is configured using Feature Report Gets and Sets and reports back gyroscope, accelerometer, magnetometer, and synchronization timestamps through an IN Report. For more information about HID, see the Device Class Definition for Human Interface Devices[1]

- **Vendor ID:** *0x2833*
- **Product ID:** *0x0021*
- **Vendor String:** *Oculus VR, Inc.*
- **Product String:** *Rift DK2*
- **Serial String:** *Globally unique 20 byte Base32 string generated per device*
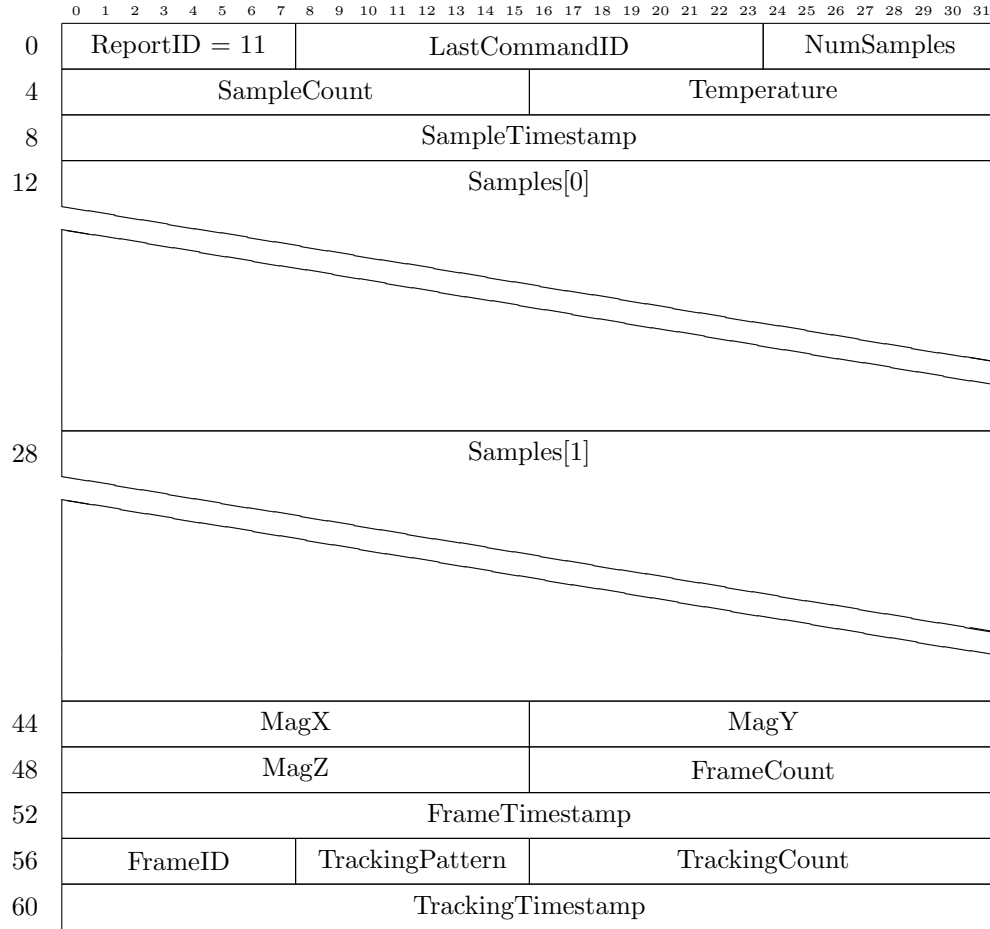
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[1]`http://www.usb.org/developers/devclass_docs/HID1_11.pdf`

3   HID In Report

The 64 byte IN report on Endpoint 1 contains the sensor data. All data is in little-endian format. The gyro and accelerometer report data at a rate of 1000 Hz, which is also the rate at which the sample time is incremented.

While the target rate for the host polling the device for the IN report is 1000 Hz, system or bus load can cause the polling to happen on longer intervals, dropping the reporting rate below 1000 Hz. For this reason, the report contains fields for up to 2 samples of gyro and accelerometer data as well as a field stating the number of samples being reported. The behavior is as follows:

- If the number of recorded samples is $<= 2$, the corresponding number of samples is returned with NumSamples set accordingly.

- If the number of recorded samples is > 2, the first (NumSamples -1) samples are averaged into Samples[0], while Samples[1] contains the most recent recorded sample. NumSamples is set to the total original number of recorded samples and Timestamp is set to that of the most recent sample; this allows for PC software to compensate the integration.

- DK2 does not accumulate more then 254 samples; beyond that the Num-Samples is reset to 2 and only the most recent 2 samples are reported, with the Timestamp field properly incremented to indicate the loss of samples.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 11	LastCommandID	NumSamples
4	SampleCount		Temperature
8	SampleTimestamp		
12	Samples[0]		
28	Samples[1]		
44	MagX		MagY
48	MagZ		FrameCount
52	FrameTimestamp		
56	FrameID	TrackingPattern	TrackingCount
60	TrackingTimestamp		

- **ReportID** (8 bits): The USB Report ID for this report is 11.

- **LastCommandID** (16 bits): Contains the CommandID from the last Feature Report set on DK2.

- **NumSamples** (8 bits): The number of samples the report represents as described above.

- **SampleCount** (16 bits): A running counter of samples, for the number of the first sample in the report. As the internal sampling rate targets 1000 Hz, this unit is close to milliseconds.

- **Temperature** (16 bits): The most recent internal sensor temperature recorded by the DK2. The value is in two's complement format, in units of centidegrees Celsius.

- **SampleTimestamp** (32 bits): A microsecond timestamp of the last sensor sample in the packet. This is recorded on the same clock as the Fram-

eTimestamp and TrackingTimestamp.

- **Samples** (128 bits): Each sample contains X, Y, and Z data for the gyro and accelerometer. Specified below.

- **MagX, MagY, MagZ** (16 bits each): The most recent data available from the magnetometer. The three axes are sampled simultaneously at up to 100 Hz. Note that consecutive reports may contain the same magnetometer data. The data is two's complement in units of 10^{-4} gauss.

- **FrameCount** (16 bit): A running counter of frames sent to the display, incremented at each vsync.

- **FrameTimestamp** (32 bit): A microsecond timestamp of the last vsync sent to the display. This is recorded on the same clock as the SampleTimestamp and TrackingTimestamp.

- **FrameID** (8 bit): The green value of the top left pixel in the last frame sent to the display. This is used to identify specific frames to measure the end to end latency from motion to photon.

- **TrackingPattern** (8 bit): The index of the last tracking LED pattern exposed to the camera.

- **TrackingCount** (16 bit): A running counter of camera frames triggered by the headset.

- **TrackingTimestamp** (32 bit): A microsecond timestamp of the last camera exposure. This is recorded on the same clock as the SampleTimestamp and FrameTimestamp.

3.1 Accelerometer and Gyro Sample

The X, Y, and Z axes of the gyro and accelerometer are sampled simultaneously. The accelerometer fields are two's complement format and 21 bits each. They are in units of $\frac{m}{s^2} \cdot 10^{-4}$. The gyroscope fields are two's complement and 21 bits each. They are in units of $\frac{\theta}{s} \cdot 10^{-4}$ in radians.

	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30 31
0	AccelX	AccelY[0:10]
4	AccelY[11:20]	AccelZ
8	GyroX	GyroY[0:10]
12	GyroY[11:20]	GyroZ

4   Feature Reports

4.1   Tracking

The 13 byte Tracking report has a ReportID of 12. It configures the infrared tracking LEDs and camera synchronization.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 12	CommandID	Pattern
4	a b c d e f		ExposureLength
8	FrameInterval		VsyncOffset
12	DutyCycle		

- **ReportID** (8 bits): The USB Report ID for this report is 12.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **Pattern** (8 bits): The index of the pattern of high and low intensities that is currently set on the tracking LEDs. Pattern 255 is reserved for all LEDs set high. Patterns auto-increment after each exposure if the Autoincrement bit is set in the bitmask. The Pattern starts at 0 on power on.

- **(a) Enable** (1 bit): This bit enables the tracking LED exposure and updating. This currently defaults to on, but will default off in a later firmware revision.

- **(b) Autoincrement** (1 bit): With Autoincrement set, the Pattern is incremented after every exposure. This defaults to on.

- **(c) UseCarrier** (1 bit): The tracking LEDs modulate at 85 kHz to allow for wireless synchronization when UseCarrier is enabled. This defaults to on.

- **(d) SyncInput** (1 bit): With SyncInput enabled, LED exposure is triggered from a rising edge on GPIO1. With SyncInput disabled, the LED exposure is triggered from an internal timer at FrameInterval. This defaults to off.

- **(e) VsyncLock** (1 bit)(Disabled): If enabled, LED exposure is triggered on panel Vsync rather than from an internal timer or external trigger. This defaults to off.

- **(f) CustomPattern** (1 bit): If enabled, the LED sequence will be the one loaded in using the CustomPattern report. This defaults to off.

- **ExposureLength** (16 bits): This is the length of time the tracking LEDs are enabled for in microseconds. The sync output also follows this length. This number cannot be larger than the FrameInterval. The minimum length is approximately 10 microseconds.

- **FrameInterval** (16 bits): When SyncInput and VsyncLock are false, the tracking LEDs are exposed on the interval set in FrameInterval in microseconds.

- **VsyncOffset** (16 bits)(Disabled): When VsyncLock is enabled, the exposure can be performed a fixed offset of VsyncOffset microseconds after the panel vsync.

- **DutyCycle** (8 bits): When UseCarrier is true, the duty cycle of the 85 kHz modulation can be increased or decreased. The default value is 128, which results in a 50% duty cycle.

4.2 Display

The 16 byte Display report has a ReportID of 13. It configures the display panel.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 13	CommandID	Brightness
4	a	b c d e f g h	
8	Persistence		LightingOffset
12	PixelSettle		TotalRows

- **ReportID** (8 bits): The USB Report ID for this report is 13.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **Brightness** (8 bits): A relative brightness setting that is independent of pixel persistence. The field only takes effect if HighBrightness is disabled.

- **(a) ShutterType** (4 bits)(Read only): A read-only enum of the method in which the display is scanned and exposed.

- **(b) CurrentLimit** (2 bit): An enum of the current limiting mode in use.

- **(c) UseRolling** (1 bit): Switches between global shutter and rolling shutter update modes. This defaults to true.

- **(d) ReverseRolling** (1 bit): Switches the polarity on the rolling shutter mode. Reverse had the lighting of rows happen before the black period. This defaults to true.

- **(e) HighBrightness** (1 bit)(Disabled): This enables a mode in which maximum brightness is used, at the possible expense of panel lifetime. This defaults to false.

- **(f) SelfRefresh** (1 bit): This sets the panel to self refresh from the contents of its frame buffer. This defaults to false.

- **(g) ReadPixel** (1 bit): This enables reading the top left pixel each frame. This currently defaults to false, but will default to true in a later firmware revision.

- **(h) DirectPentile** (1 bit): This enables direct mapping of input data to panel sub pixel geometry, rather than using in-panel interpolation.

- **Persistence** (16 bits): This is the length of time in rows that the display is lit each frame. This defaults to the full size of the display, meaning full persistence.

- **LightingOffset** (16 bits)(Disabled): This is the offset in rows from vsync that the panel is lit when using global shutter mode. In rolling shutter, this has no effect.

- **PixelSettle** (16 bits)(Read only): This is the read-only time in microseconds that we estimate the pixel takes to settle to the value it is set to after it is lit.

- **TotalRows** (16 bits)(Read only): This is the read-only number of rows including active area and blanking used with Persistence and LightingOffset.

4.3   MagCalibration

The 52 byte MagCalibration report has a ReportID of 14. It contains the 3 by 4 matrix of parameters used to fit the magnetometer to a sphere. The table is stored on the headset, but the firmware does not apply it to outgoing magnetometer data.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 14	CommandID	Version
4	Calibration[0][0]		
8	Calibration[0][1]		
12	Calibration[0][2]		
16	Calibration[0][3]		
20	Calibration[1][0]		
24	Calibration[1][1]		
28	Calibration[1][2]		
32	Calibration[1][3]		
36	Calibration[2][0]		
40	Calibration[2][1]		
44	Calibration[2][2]		
48	Calibration[2][3]		

- **ReportID** (8 bits): The USB Report ID for this report is 14.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **Version** (8 bits): The version of the calibration procedure used to generate the stored table.

- **Calibration** (48 bytes): This is the 3 by 4 matrix used to fit magnetometer data to a sphere. Each field is a 32 bit signed integer. The specific value is dependent on the calibration procedure, indicated by Version.

4.4   PositionCalibration

The 30 byte PositionCalibration report has a ReportID of 15. It allows reading and storage of calibrated positions of each tracking LED as well as the inertial tracker.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 15	CommandID	Version
4	Position[0]		
8	Position[1]		
12	Position[2]		
16	Normal[0]		Normal[1]
20	Normal[2]		Rotation
24	PositionIndex		NumPositions
28	PositionType		

- **ReportID** (8 bits): The USB Report ID for this report is 15.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **Version** (8 bits): The version of the calibration procedure used to generate the stored positions. Note that setting the report with a Version value of 1 returns the Position values for the PositionIndex to the stored defaults.

  0 - None

  1 - Hard-coded default positions

  2 - Factory calibrated

  3 - User calibrated

- **Position** (12 bytes): The X, Y, and Z axis position of the LED or inertial tracker. This is a signed integer in units of micrometers. The position is relative to the center of the emitter plane of the display at nominal focus.

- **Normal** (6 bytes): The X, Y, and Z axis normal of the LED or inertial tracker. This is a signed integer in units of micrometers. The Normal is relative to the Position.

- **Rotation** (16 bits): The rotation around the normal. This is in units of 10^{-4} radians.

- **PositionIndex** (16 bits): This is the current position being read or written to. This autoincrements on reads, and gets set to the written value

on writes.

- **NumPositions** (16 bits)(Read only): This is the read-only number of items with positions stored.

- **PositionType** (16 bits)(Read only): The type of the item which has its position reported in the current report. These are defined as:

  0 - Tracking LED

  1 - Inertial sensor

  When setting this report, the PositionType should match that read for the PositionIndex.

4.5 CustomPattern

The 12 byte CustomPattern report has a ReportID of 16. It allows reading of the default LED patterns as well as reading and setting of custom patterns. Repeated reads of the report iterate through each LED, starting at 0 and wrapping at the final LED. When the CustomPattern bit of the Tracking report is not set, reads on this report act upon the default LED pattern stored in the headset, and writes have no effect. With the CustomPattern bit set, this report acts on a custom pattern array that erases when the headset is reset.

0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0 ReportID = 16	CommandID	SequenceLength
4	Sequence	
8	LEDIndex	NumLEDs

- **ReportID** (8 bits): The USB Report ID for this report is 16.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **SequenceLength** (8 bits): The length of the sequence of bits that each LED goes through. Each state of the sequence is represented by two bits, allowing a maximum of 4 levels per sequence. For DK2, only states 0, 1, and 3 are meaningful, for off, low, and high respectively.

- **Sequence** (32 bits): The sequence that the specific LED goes through. The first $SequenceLength * 2$ bits are used. The sequence is in order of LSB to MSB.

- **LEDIndex** (16 bits): This is the current LED being read or written to. This autoincrements on reads, and gets set to the written value on writes.

- **NumLEDs** (16 bits)(Read only): This is the read-only number of tracking LEDs which are actually present on the device.

4.6 KeepAliveMux

The 6 byte KeepAliveMux report has a ReportID of 17. It is used to specify both which IN Report is sent and the interval of sending. The interval takes effect only if the UseCommandKeepAlive or UseMotionKeepAlive bits are set in the Config report.

0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0 ReportID = 17	CommandID	INReport
4 Interval		

- **ReportID** (8 bits): The USB Report ID for this report is 17.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **INReport** (8 bits): The specified number is the INReport which will be repeatedly sent until the interval is passed. For example, specifying 1 sends the DK1 IN Report, while specifying 11 sends the DK2 IN Report. The default value for DK2 is 11.

- **Interval** (16 bits): The interval in milliseconds used as the threshold for UseCommandKeepAlive and UseMotionKeepAlive. The default interval is 10000.

4.7 Manufacturing

The 16 byte Manufacturing report has a ReportID of 18. It is used to record and display the results of each stage of the production of the DK2 product that has USB access.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 18	CommandID		NumStages
4	Stage	StageVersion	StageLocation	
8	StageTime			
12	Result			

- **ReportID** (8 bits): The USB Report ID for this report is 18.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **NumStages** (8 bits)(Read only): The number of stages of production being recorded on the product.

- **Stage** (8 bits): The specific stage number being recorded or read from. This autoincrements on reads, and gets set to the written value on writes.

- **StageVersion** (8 bits): The version of the specific manufacturing test.

- **StageLocation** (16 bits): A bit mask representing the manufacturer, line, and machine this test was performed on. See the DK2 Testware document for details on this.

- **StageTime** (32 bits): The UNIX time at which the stage was performed.

- **Result** (32 bits): The result of the stage. See the DK2 Testware document for the details of what this means for each stage.
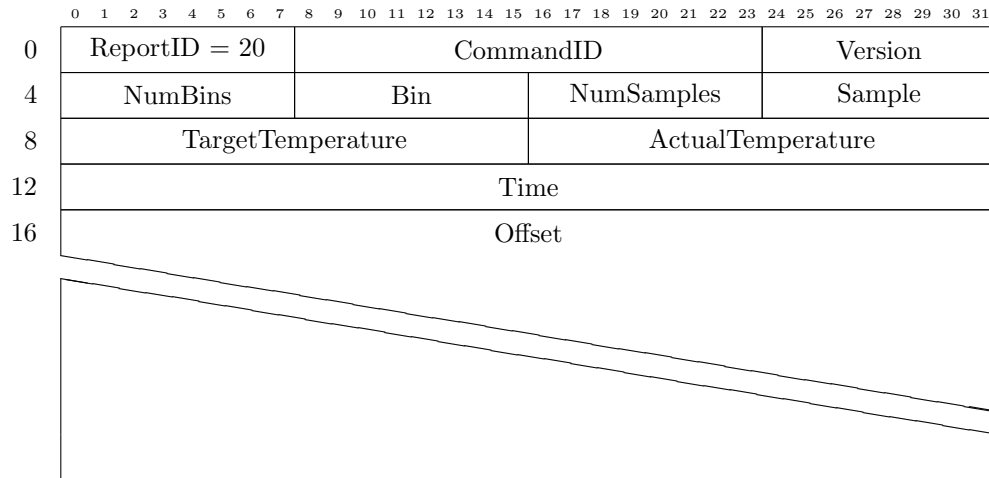
4.8 UUID

The 23 byte UUID report has a ReportID of 19. It is used internally for manufacturing purposes, when the USB serial number is set to a default number. Outside of manufacturing, the number is identical to the USB serial number. Setting this report switches the USB serial number to the value read from this report. The value being set is ignored.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 19	CommandID	UUID[0]
4	UUID[1:5]		
8	UUID[5:9]		
12	UUID[9:13]		
16	UUID[13:17]		
20	UUID[17:20]		

- **ReportID** (8 bits): The USB Report ID for this report is 19.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **UUID** (20 bytes)(Read only): The unique ID of the device.

4.9 Temperature

The 24 byte Temperature report has a ReportID of 20. It is used to store gyroscope zero rate offsets across different temperatures. The offsets are stored for certain target temperature Bins, with multiple Samples of offset data stored per temperature. When reading the report, subsequent reads of the report go sequentially through each Sample in NumSamples for each Bin in NumBins. The headset only stores the offsets, and does not create or modify them directly.

|	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 20	CommandID		Version
4	NumBins	Bin	NumSamples	Sample
8	TargetTemperature		ActualTemperature	
12	Time			
16	Offset			

- **ReportID** (8 bits): The USB Report ID for this report is 20.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **Version** (8 bits): The version of temperature calibration being performed.

- **NumBins** (8 bits)(Read only): The number of temperature bins being stored.

- **Bin** (8 bits): The current index of temperature bin the samples are for. This autoincrements on reading all of the Samples in the Bin, and gets set to the written value on writes.

- **NumSamples** (8 bits)(Read only): The number of samples being stored per temperature bin.

- **Sample** (8 bits): The current index of temperature offset sample. This autoincrements on reads, and gets set to the written value on writes.

- **TargetTemperature** (16 bits)(Read only): The target temperature in centidegrees Celsius for the current Level.

- **ActualTemperature** (16 bits): The actual temperature in centidegrees Celsius of the current Bin.

- **Time** (32 bits): The UNIX time that the current Sample was generated at.

- **Offset** (64 bits): The packed sample format with 21 bits per axis used for the IN Report, with each value in units of $\frac{\theta}{s} \cdot 10^{-4}$ radians, representing the estimated zero-rate gyroscope offset for the ActualTemperature.

4.10   GyroOffset

The 18 byte Temperature report has a ReportID of 21. It is used to fetch the
headset's most recent estimate of gyro zero-rate offset error. Note that if the
headset fails to complete zero rate offset calculation, there will not be valid data
in this report, indicated by a Version field value of 0.
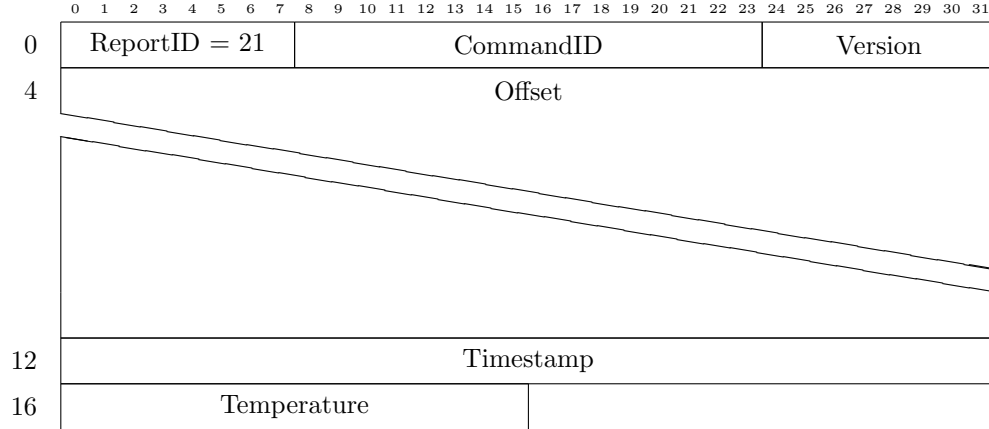
- **ReportID** (8 bits): The USB Report ID for this report is 21.

- **CommandID** (16 bits): A sequence number that is then repeated in the
  LastCommandID field of the HID IN Report.

- **Version** (8 bits): The version of offset calculation being performed.

  0 - No offset calculated

  1 - Running average terminated by motion

  2 - Running average terminated by timeout

- **Offset** (64 bits): The packed sample format with 21 bits per axis used for
  the IN Report, with each value in units of $\frac{\theta}{s} \cdot 10^{-4}$ radians, representing
  the estimated zero-rate gyroscope offset.

- **Timestamp** (32 bits): A microsecond timestamp of the calculation of the
  offset. This is recorded on the same clock as the SampleTimestamp in the
  IN Report.

- **Temperature** (16 bits): The temperature the offset was calculated at.

4.11   LensDistortion

The 64 byte LensDistortion report has a ReportID of 22. It defines parameters used by LibOVR to correct lens distortion. Multiple reports of the same or different versions or eye reliefs may be available, defined by NumDistortions. The report defaults to factory data, but each DistortionIndex may be overwritten with new data.

	0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
0	ReportID = 22	CommandID	NumDistortions
4	DistortionIndex	Bitmask	LensType
8	Version		EyeRelief
12	KCoefficients[0]		KCoefficients[1]
16	KCoefficients[2]		KCoefficients[3]
20	KCoefficients[4]		KCoefficients[5]
24	KCoefficients[6]		KCoefficients[7]
28	KCoefficients[8]		KCoefficients[9]
32	KCoefficients[10]		MaxR
36	MetersPerTanAngleAtCenter		ChromaticAberration[0]
40	ChromaticAberration[1]		ChromaticAberration[2]
44	ChromaticAberration[3]		
48	Unused		

- **ReportID** (8 bits): The USB Report ID for this report is 22.

- **CommandID** (16 bits): A sequence number that is then repeated in the LastCommandID field of the HID IN Report.

- **NumDistortions** (8 bits)(Read only): The number of lens distortions being stored.

- **DistortionsIndex** (8 bits): The current index of lens distortion. This autoincrements on reads and gets set to the written value on writes.

- **Bitmask** (8 bits): A current unused bitmask.

- **LensType** (16 bits): The type of the lens used in the headset. These are enumerated in LibOVR.

- **Version** (16 bits): The version of lens distortion specified in the report. The fields after this one are dependent on the specified Version.

  0 - No lens distortion stored. The remaining report is empty.

  1 - LCSV_CatmullRom10Version1. The fields are defined as below.

- **EyeRelief** (16 bits): The eye relief the distortion is designed for. This is in units of micrometers measured from the front surface of the lens.

- **KCoefficients** (11 fields of 16 bits): Catmull-Rom distortion coefficients. The units are defined in LibOVR.

- **MaxR** (16 bits): Defined in LibOVR.

- **MetersPerTanAngleAtCenter** (16 bits): Defined in LibOVR.

- **ChromaticAberration** (4 fields of 16 bits): Defined in LibOVR.

- **Unused** (14 bytes): Unused by LCSV_CatmullRom10Version1.

5   EDID

The EDID 1.3 is read over the HDMI interface by the video host.

- **Manufacturer ID:** *OVR*
- **Product ID:** *0x0003*
- **Product String:** *Rift DK2*
- **Serial String:** *First 13 bytes of the device UUID*