Optical Data Interface
ODI-2.1 High Speed Data Formats
Preliminary Specification

Revision 2, Date 180420

The ODI Specification is managed by the AXIe Consortium.
For more information about ODI, go to http://axiestandard.org/odispecifications.html
For more information about the AXIe Consortium, go to http://axiestandard.org

ODI 3-part Specification

ODI-2.1: High-Speed Formats

- 8 to 16 bit data formats
- Packing Methods
- Optimized for SDR & 5G

Data Formats

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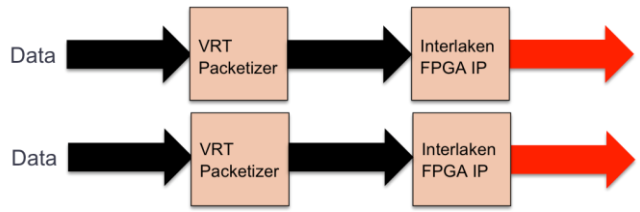
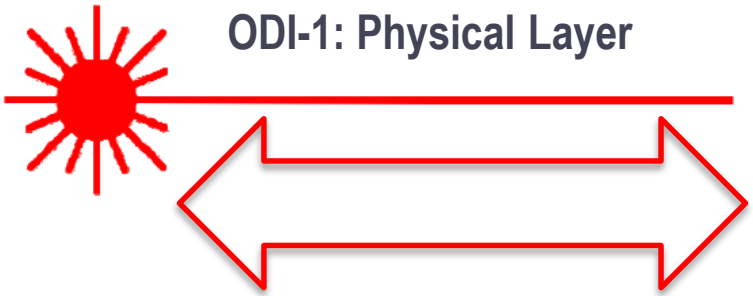
ODI-2: Transport Layer



- VITA-49 "VRT" Packets
- FPGA Optimized
- Port Aggregation
- Context Packets

Transport Layer

ODI-1: Physical Layer



- 12 lane multimode optics
- 12.5 & 14.1 Gb/s
- Interlaken Protocol
- Flow Control

Physical Layer

ODI-2.1 Scope

- The ODI-2 High Speed Data Formats sits one level higher than the ODI-2 Transport Layer, and is essentially a subset of the ODI-2 packet structure to encourage interoperability between ODI devices.

- The ODI-2.1 standard is at an equivalent level to VITA 49A-2015 Spectrum Survey Interoperability Specification, but focuses specifically on formats suitable for high speed streaming and FPGA processing.

- ODI-2.1 defines a standard ODI-2.1 Data Packet, including data formats for high speed multi-channel sample data from 8 to 16 bits of resolution. This range addresses applications in wireless communications, 5G cellular, radar, electronic warfare, and high-speed data acquisition.

- ODI-2.1 also defines
  - A standard but optional ODI-2.1 Context Packet
  - A standard but optional ODI-2.1 Control Packet
  - A method for expanding data formats to all data formats described in VITA 49A.

ODI-2.1 Compliance

- RULE: All implementations of of this specification SHALL comply with all the rules in this specification.
- RULE: All implementations of of this specification SHALL comply with all the requirements in the Interlaken Protocol Definition, Revision 1.2 or later.
- RULE: All implementations of of this specification SHALL comply with all the requirements in the VITA 49.2-2017 VITA Radio Transport (VRT) standard
- RECOMMENDATION: All implementations of of this specification SHOULD comply with all the recommendations in this specification.
- RULE: All implementations of of this specification SHALL clearly specify any and all deviations from the recommendations in this specification.
- RULE: All implementations of of this specification SHALL comply with the documentation requirements of this specification

Glossary - 1

- Device
  - An assembly that generates or receives data and has one or more optical ports
- Port
  - A single optical connector on a device, and the associated electronics
- Cable
  - A multiple fiber cable that connects between two ports
- Link
  - A unidirectional connection between two ports, consisting of 12 lanes of multimode optical transmission. A bi-directional connection has two links, one in each direction.
- Producer
  - ODI device that generates data to be sent over one or more optical ports
- Consumer
  - ODI device that receives data sent over one or more optical ports
- Transmitter
  - Interlaken term for a producer
- Receiver
  - Interlaken term for a consumer. VITA term for an RF receiving device.
- Emitter
  - VITA term for a producer.
- Exciter
  - VITA term for an RF signal generator

Glossary - 2

- Interlaken
  - Interlaken is the name of a chip-to-chip interface specification that is used by ODI to transfer packets between two ODI ports. It is the primary communication protocol. Separately, the packet structure sent over Interlaken is defined to be VRT, defined in the ODI-2 specifications.
- VRT
  - VRT is an abbreviation for VITA Radio Transport, standardized in VITA 49.2, and enhanced by other VITA 49x specifications. VRT specifies the structure and behavior of VRT packets, which carry data, context, and control information about signals, and the data stream itself. VITA 49 may be abbreviated as V49, as VITA 49.x may be abbreviated as V49.x
- Channel
  - "Channel" is used differently in Interlaken specifications than is commonly understood in operational or instrumentation systems as a signal channel.
  - Channel is used by Interlaken to enable a completely different data stream with its own flow control. ODI generally uses only a single Interlaken channel.
  - Channel is used by VRT similarly to instrumentation systems.
  - Synchronous instrumentation channels are encoded into the VRT stream in a rotating sequence, and are referred to as a "sample vector" in VRT parlance. VRT Sample Vector Size field is the number of instrumentation channels minus 1. This assumes synchronous channels, all at the same data rate and resolution.

Glossary - 3

- Word
  - An Interlaken Word is 8 bytes (64 bits)
  - A VRT Word is 4 bytes (32 bits)
- Burst
  - In Interlaken, data is divided into data bursts, each delineated by one or more burst control words.
- BurstMax
  - An Interlaken parameter that determines the maximum number of data bytes sent for each burst. Typically, streaming data will be set with these burst lengths. ODI allows 256 and 2048 byte BurstMax.
- BurstShort
  - An Interlaken parameter that reflects the shortest burst allowed.
- BurstMin
  - An Interlaken parameter for the Optional Scheduling Enhancement that guarantees all packets are at least BurstMin in length, and no idle control words will be needed for long packets.
- Packet
  - A packet refers to the block of data sent between Interlaken SOP and EOP (Start of Packet and End of Packet) indicators. At the Interlaken layer, the format of the packet is unknown. ODI-2 has defined the packet to be VRT packets. The term packet within ODI refers to both.

Glossary - 4

- Prologue
  - The Prologue refers to fields within a VRT data, context, or command packet that precede the data payload or context/command data payload respectively. A standard 28-byte Prologue is defined for each packet type.
- Trailer
  - The Trailer refers to the 4-byte field that follows the data payload within a VRT Data packet. There is no trailer associated with Context Packets or Command Packets.
- Processing-efficient packing
  - Processing-efficient packing refers to a data packing method within the VRT Packet data payload where the packed data is aligned to 32-bit boundaries.
- Link-efficient packing
  - Link-efficient packing refers to a data packing method within the VRT Packet data payload where the data is packed as tightly as possible, leading to the highest sample density and speed.

Glossary - 5

- Stream
  - A VRT term for a sequence of related packets. All packets of the same stream have the same Stream ID sent from the producer. A typical stream has consecutive Signal Data Packets, with optional Context Packets and/or Command Packets occasionally.
- Signal Data Packets
  - VRT term for a packet carrying digitized samples of one or more signals. This is the primary packet type of ODI. Most ODI systems will only include Signal Data Packets.
- Context Packet
  - VRT term for a packet carrying meta-data or “context” data related to the digitized signals in the same stream. This may include information such as reference level or sampling rate. Context Packets are optional in ODI, but a standard Context Packet is defined in ODI-2.1 if used.
- Command Packet
  - VRT term added in V49.2. Command Packets are used to control devices, and the control and acknowledgement process. The Control Packet is the only recommended Command Packet subtype, and has the same field types as the Context Packet, which are used for control. Control and other Command Packets are optional in ODI, but a standard Control Packet is defined in ODI-2.1 if used.

Glossary - 6

- Extension Packet
  - Extension Signal, Context, and Command packets are used when it is impossible to use the pre-defined data types. An example may be the sending of encrypted data.
- Train
  - For streaming applications, the Train refers to a series of packets, typically of the same size, sent sequentially from a producer, but not including the final packet, called the Caboose
- Caboose
  - For streaming applications, the Caboose refers to the final packet sent from the producer. It may or may not be the same size as the Train packets.
- Sample Vector
  - A Sample Vector is defined within V49.2 as a collection of synchronous Data Samples. This is the common method of transporting multi-channel sample data within the VRT data payload fields. Vector size describes the number of channels. However, the VRT Vector Size Field, used in V49.2 and ODI-2.1, is calculated as the vector size minus one. Therefore a two-channel stream has a vector size of two, but a Vector Size Field of 1.

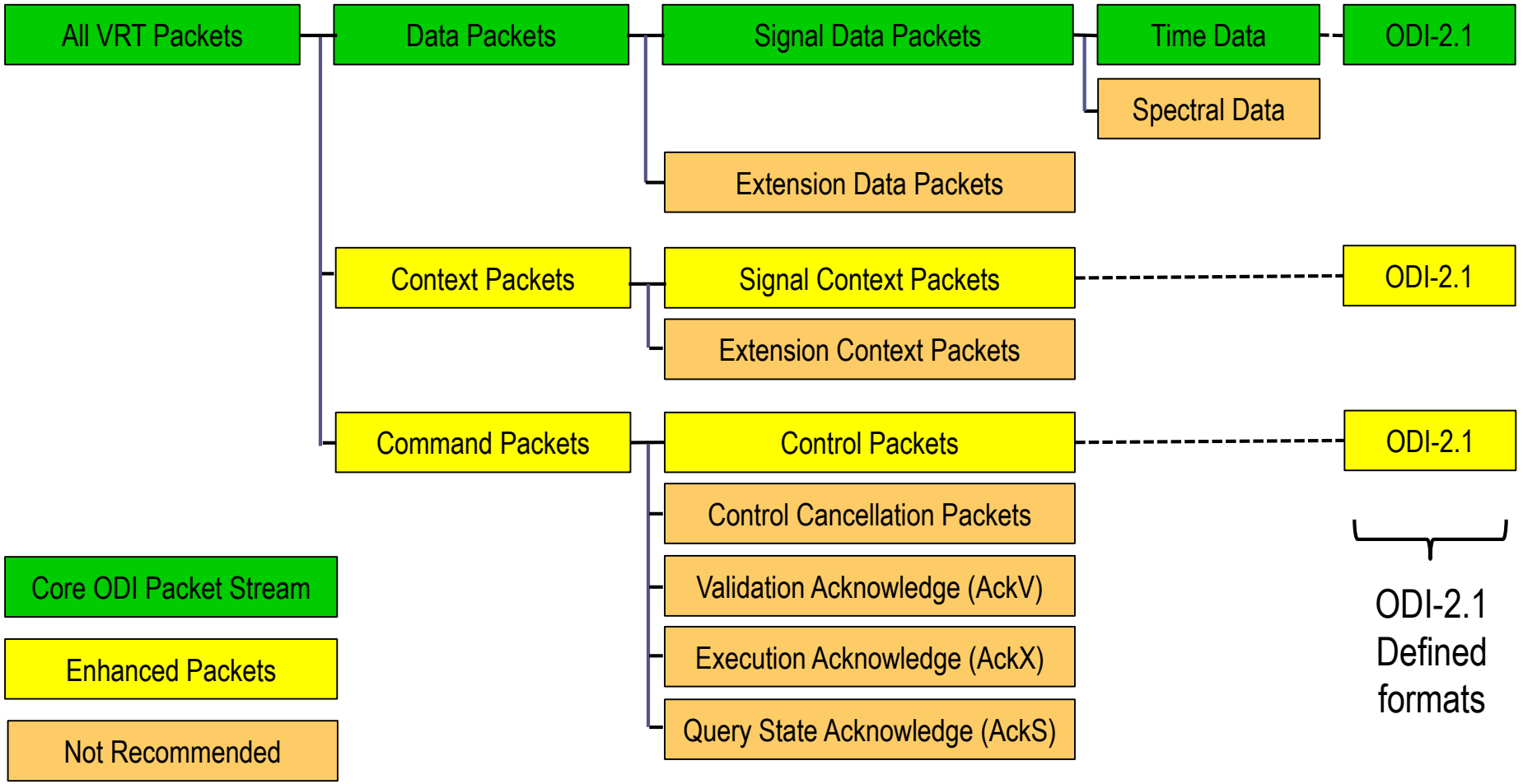
ODI-2.1 What is it?

- ODI-2 is a data format specification designed to increase interoperability between ODI devices.
- ODI-2.1 specifies the data formats for high speed sample data transfers from an ODI producer to an ODI consumer. ODI-2.1 builds on top of the VITA 49.2 VITA Radio Transport (VRT) standard outlined in ODI-2 to specify data formats for improved interoperability between devices. ODI-2.1 specifies the requirements for both, sample data and context/command data.
- ODI-2.1 uses standardized VRT Signal Data Packets, VRT Signal Context Packets, and VRT Command Packets. Context and Command packets are designed to be used with the Data packets.
- ODI-2.1 specifies the format and packing of signed binary data from 8 bits of resolution to 16 bits of resolution.
  - ODI-2.1 mandates the handling of 8 and 16 bit sample data
  - ODI-2.1 describes the optional capability of handling of 9 through 15 bit link-efficient packed data
  - ODI-2.1 describes the optional capability of indicating events, such as markers.
  - ODI-2.1 optionally allows other VITA 49A data formats.
- ODI-2.1 specifies a standard, but optional, 96-byte Context packet and a similar 96-byte Control packet.

VRT Packet Hierarchy for ODI

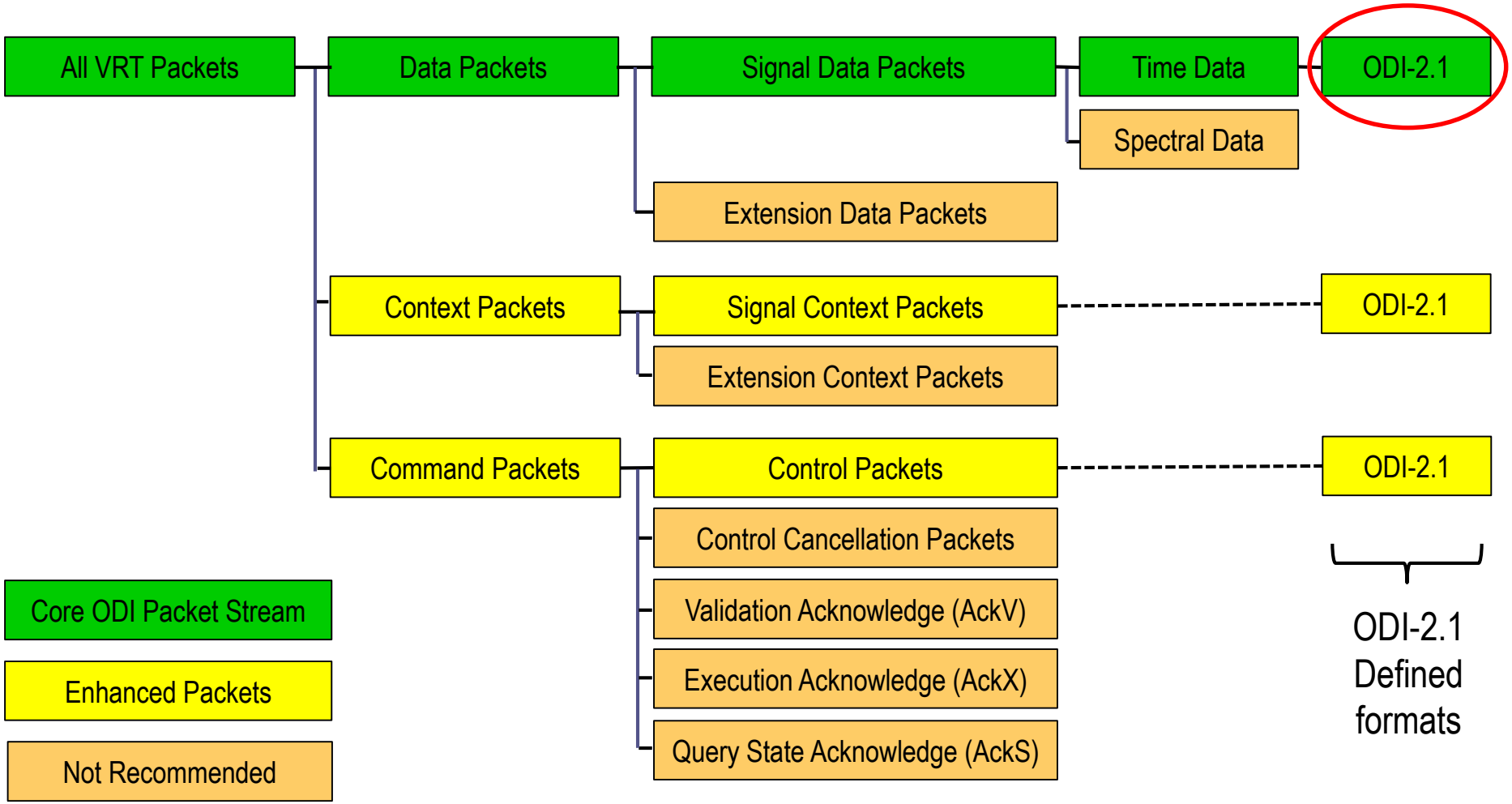
- The following figure shows the packet hierarchy for ODI-2 and ODI-2.1.
- The principal ODI Packet Stream consists of consecutive Signal Data Packets sending Time Data. No other Packet Streams are required. It is expected that many ODI systems will be built using only Signal Data Packets. ODI-2.1 further defines standard Signal Data Packets formats for interoperability. These are known simply as ODI-2.1 Data Packets.
- Context Packets optionally send additional information about the signal. ODI-2.1 further defines a standard Context Packet for interoperability. These are known simply as ODI-2.1 Context Packets.
- Control Packets, a subset of Command Packets, are similar to Context Packets but send additional information as commands to be executed. ODI-2.1 further defines a standard Control Packet for interoperability. These are known simply as ODI-2.1 Control Packets.
- Packet subtypes marked in orange are not recommended. However, ODI-2 specifies the rules for implementing those packet subtypes if needed.
- The following figure will be used repeatedly in the remainder of the ODI-2.1 specification to describe the rules and recommendations of the various packets and packet subtypes.

VRT Packet Hierarchy for ODI



ODI-2.1 Data Packet Specifications

ODI-2.1 Data Packet Specifications

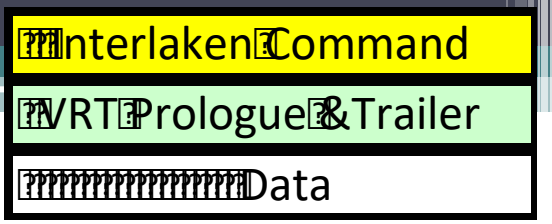


ODI-2.1 Data Packet Formats

- RULE: ODI-2.1 devices SHALL comply with the Signal Data Packets described in ODI-2.

- The structure of an ODI-2 Data Packet is shown in the following two slides. These are taken directly from ODI-2.

Packet structure - Data

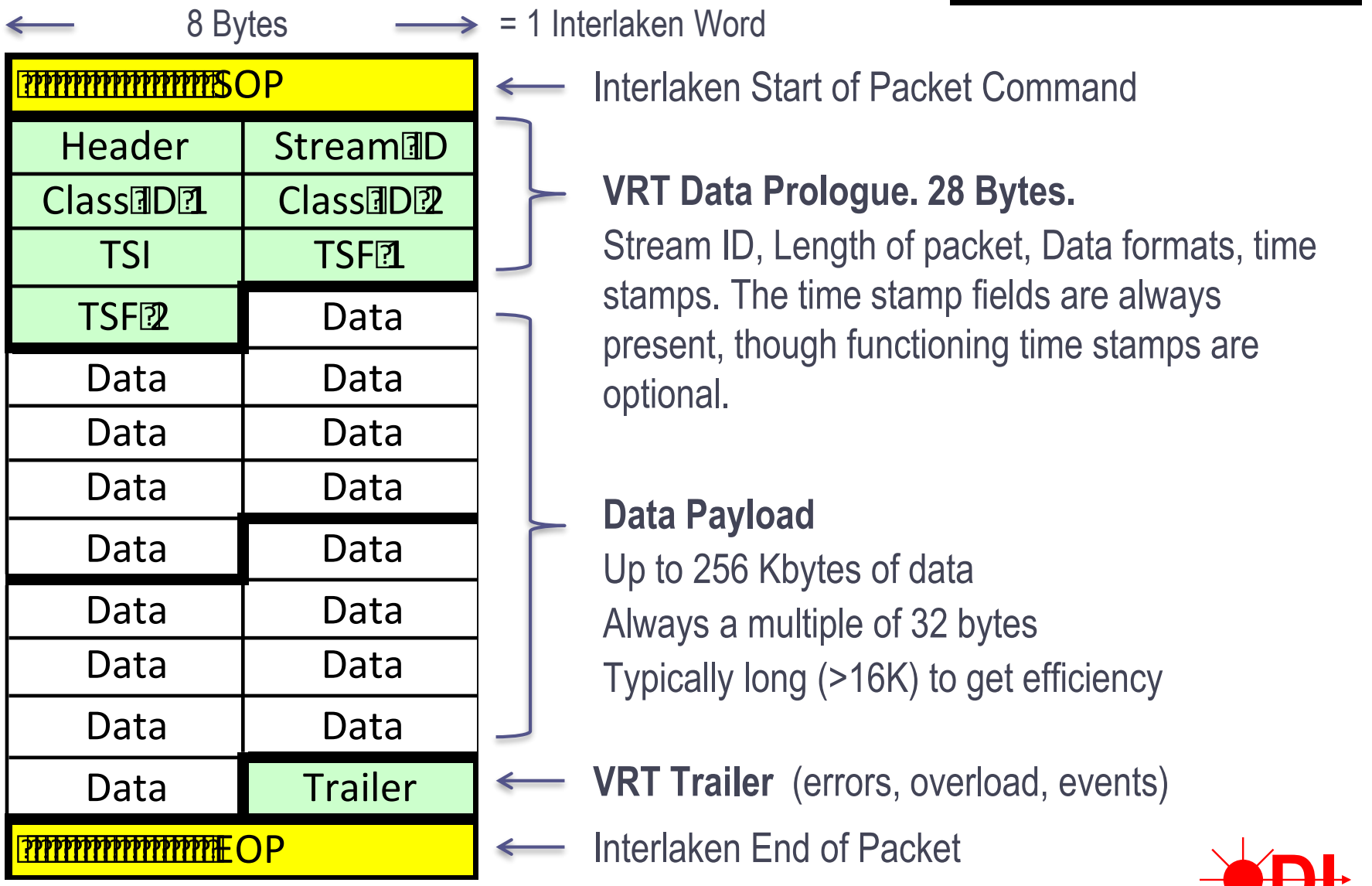


← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Trailer
EOP	

- RULE: ODI-2 devices sending data SHALL comply with the Data Packet and Streams section of VITA 49.2, Section 6.
- OBSERVATION: VITA 49.2 specifies two data packet types, Signal Data and Extension Data, but they have similar Prologue and Trailer requirements.
- The Prologue is the mandated 28 Bytes that precedes the data.
- RULE: ODI-2 devices SHALL include all seven Prologue fields plus the Trailer field, as defined in VITA-49.2
- RULE: ODI-2 devices SHALL comply with the diagrams and descriptions of each field.

Packet structure - Data



Data Packet Structure, Header

- The figure below shows the content of the mandatory header for data packets, and is reflective of VITA 49.2 Signal Data packets.
- RULE: Packet Type (28-31) SHALL be set to 0001
- RULE: All other fields within the Header, other than Packet Type, SHALL behave as specified in ODI-2.
- OBSERVATION: The only difference between ODI-2 and ODI-2.1 in the Data Packet Header field is that ODI-2.1 mandates an Signal Data Packet, while ODI-2 allows either a Signal Data Packet or an Extension Data Packet.

VRT Packet Header

Word	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	Packet Type				C	*Indica-tors*			TSI		TSF		Packet Count				Packet Size															

V49.2 Figure 5.1.1-1: VRT Packet Header

Data Packet Structure, Stream ID

- Stream ID is an abbreviation for Stream Identifier
- The Stream ID is a 32-bit field, whose value is the same for all data and context packets associated with that stream
- RULE: All ODI-2 and ODI-2.1 devices SHALL include a Stream ID field
- RULE: The default Stream ID for a single port device SHALL be 4096, as shown in the diagram below.
- OBSERVATION: Default Stream ID of 4096 matches the default Stream ID of VITA 49A.
- RULE: In a multi-port device where the ports are to be aggregated, each additional port's Stream ID SHALL be incremented by 1024 by default.
- OBSERVATION: In a 4-port aggregation, the Stream IDs are

  Port 1: 4096

  Port 2: 5120

  Port 3: 6144

  Port 4: 7168
- OBSERVATION: By incrementing by 1024 for each additional port, each port can be identified by the Stream ID. Incrementing by 1024 still allows downstream devices processing the data to increment the Stream ID by 1, as envisioned by VITA 49A, without causing duplication of Stream ID.
- RULE: Stream ID SHALL be programmable by the user.

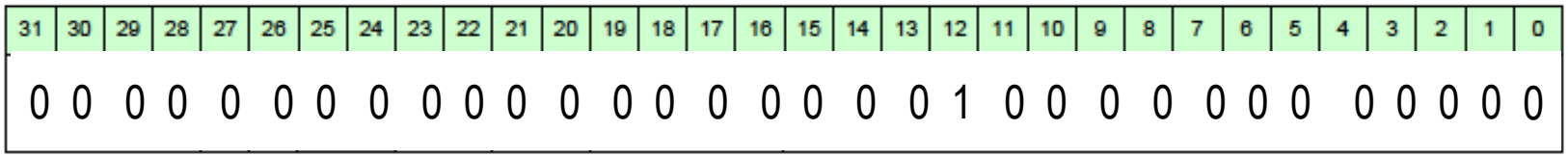
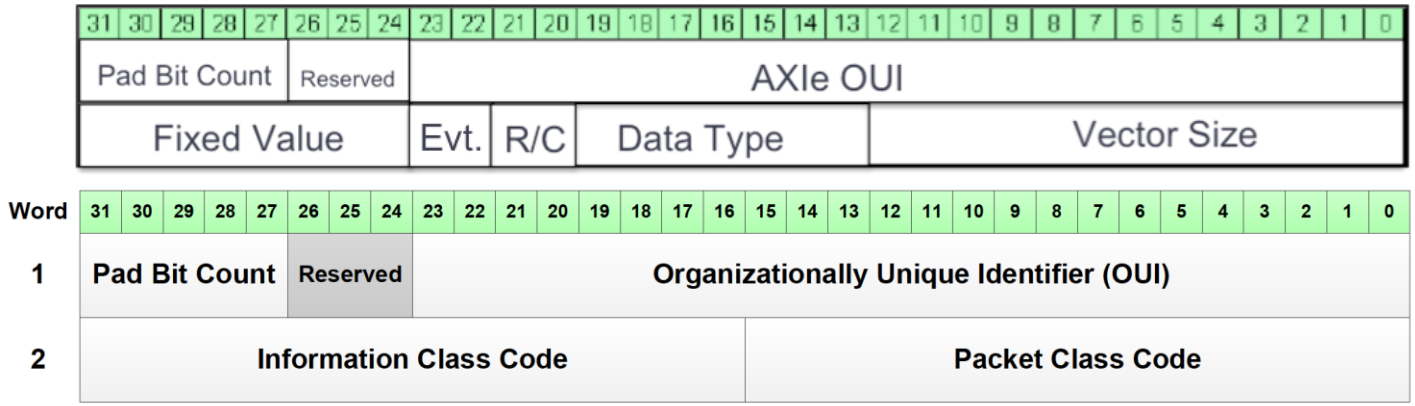


Figure shows Stream ID field configured for Stream ID= 4096

Data Packet Structure, Class ID

- The purpose of Class ID is to identify the Information Class used for the application, and the Packet Class from which each packet was made. ODI-2.1 algorithmically assigns values to the Information Class Code and Packet Class Code fields that reflects the number of signal channels, the resolution of the channels, and the packing method. This allows a consumer of data to identify the format being used.
- RULE: OUI SHALL be set to the AXIe OUI of 2-4-5-C-C-B
- Reserved (24-26) is set to 0 per VITA 49.2
- Pad Bit Count (27-31) is set per VITA 49.2
- OBSERVATION: The Reserved and Pad Count fields act exactly the same as in ODI-2.



ODI-2.1

VITA 49.2 and ODI-2

Figure 5.1.3-1: Contents of the Class ID Field

ODI-2.1 vs. VITA 49A

- VITA 49A defines a set of data formats for improved interoperability, much like ODI-2.1. VITA 49A included a number of data structures for 32 to 64-bit processors, while ODI-2.1 focuses on high-speed transfers, typically 8 to 16-bit data formats.
- Both standards use an algorithm to define the Class ID Field so that an observer can determine the data format and the number of channels in the data payload.
- ODI-2.1 defines the Class ID Field algorithm to be compatible with VITA 49A, but expanding it for link-efficient packing of signed binary data, real and complex.
- ODI-2.1 accomplishes this by repurposing the three most significant bits of the Vector Size Field within VITA 49A to be an extension of the Data Type Field. This reduces the number of channels possible from 64K to 8K, which has minimal impact in practical systems.
- The key difference between the standards is that ODI-2.1 mandates the use of 8-bit and 16-bit signed binary data, and allows the use of link-efficient packing of 9 to 15-bit data.
- ODI-2.1 also allows the insertion of events on a per-sample basis, indicated by the Evt. Field.

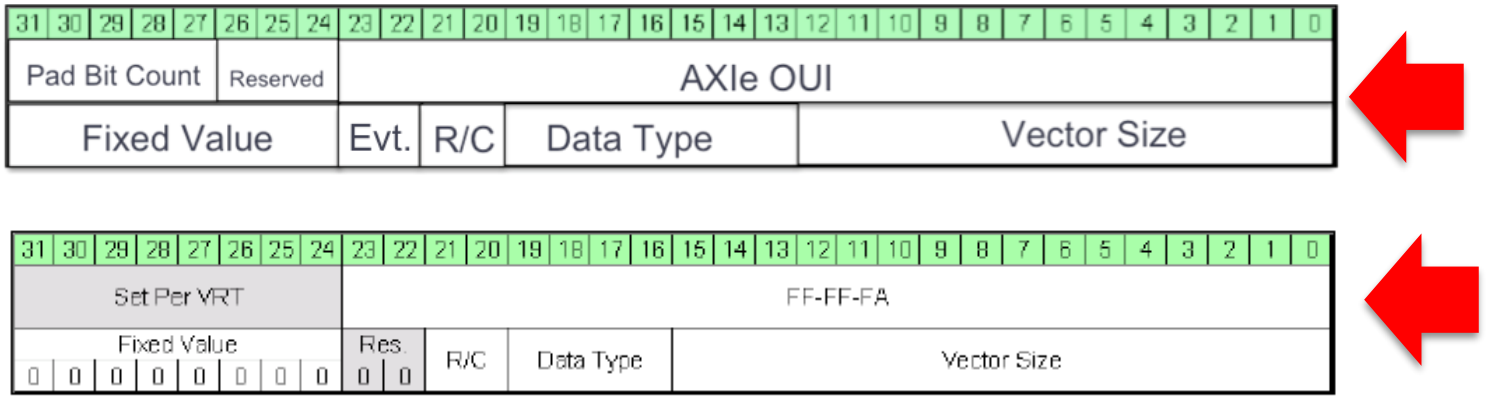
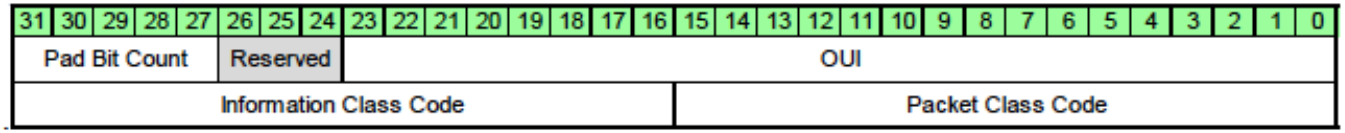


Figure 6.3-1 Organization of the Standard Data Packet Class Identifier

Data Packet Structure, Information and Packet Class Codes

- The second 32-bit word of the Class ID field consists of the Information Class Code and the Packet Class Code.
- In ODI-2.1, these codes are algorithmically defined using the five sub-fields:
  - Fixed Value — Fixed Value SHALL be set to 0.
  - Evt. — Evt. (Event) SHALL be set as per the Evt. Table.
  - R/C — Real/Complex SHALL be set as per the Real/Complex table
  - Data Type — Data Type SHALL be set as per the Data Type table
  - Vector Size — Vector Size SHALL be set via the rules defined for the count of multiple channels.

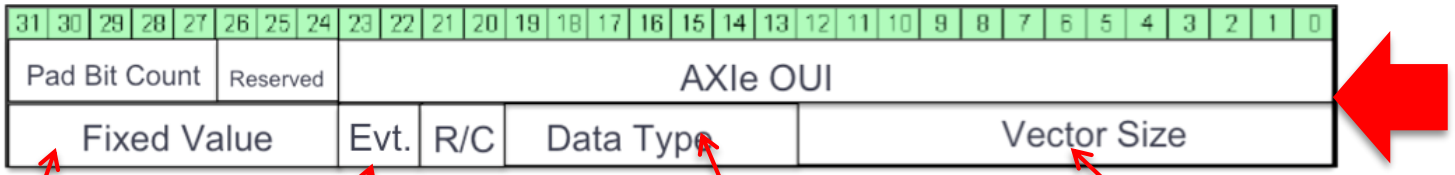
ODI-2.1



VITA 49.2 and ODI-2

Figure 6.1.3-1: The Contents of the Class ID Field

Data Packet Structure, Information and Packet Class Codes



ODI-2.1

Fixed Value is set to zero.

Vector Size = number of signal channels minus1

Evt. (Event):
00 = No Event bits
01 = 1 Event bit
10 = 2 Event bits
11 = 4 Event bits

R/C (Real/Complex):
00 = Real
01 = Complex/Cartesian

0010 000= 8-bit Signed Fixed Point
0011 000= 16-bit Signed Fixed Point
0000 001= 9-bit Signed Fixed Point, link-efficient packing
0000 010= 10-bit Signed Fixed Point, link-efficient packing
0000 011= 11-bit Signed Fixed Point, link-efficient packing
0000 100= 12-bit Signed Fixed Point, link-efficient packing
0000 101= 13-bit Signed Fixed Point, link-efficient packing
0000 110= 14-bit Signed Fixed Point, link-efficient packing
0000 111= 15-bit Signed Fixed Point, link-efficient packing

Important: The number of bits indicated for data type is the item length. The item length is the same as the the data item length if there are no Events indicated in the Evt. Field.
Otherwise, the Data length = item length – event bits.

Data Packet Structure, Common Class IDs

Item Packing Field Width	Data Item (signed)	Event bits	Real or IQ	Channels	Class ID Hexadecimal Value
8	8-bit fixed pt.	0	Real	1	00245CCB 00020000
8	8-bit fixed pt.	0	Real	2	00245CCB 00020001
8	8-bit fixed pt.	0	Real	4	00245CCB 00020003
8	8-bit fixed pt.	0	IQ	1	00245CCB 00120000
10	10-bit fixed pt.	0	Real	1	00245CCB 00004000
10	10-bit fixed pt.	0	Real	2	00245CCB 00004001
12	12-bit fixed pt.	0	Real	1	00245CCB 00008000
14	14-bit fixed pt.	0	Real	1	00245CCB 0000C000
16	12-bit fixed pt.	4	Real	1	00245CCB 00C30000
16	14-bit fixed pt.	2	Real	1	00245CCB 00830000
16	14-bit fixed pt.	2	IQ	1	00245CCB 00930000
16	16-bit fixed pt.	0	Real	1	00245CCB 00030000
16	16-bit fixed pt.	0	Real	2	00245CCB 00030001
16	16-bit fixed pt.	0	Real	4	00245CCB 00030003
16	16-bit fixed pt.	0	IQ	1	00245CCB 00130000
32	32-bit IEEE-754 floating point	0	Real	1	00245CCB 00060000
32	32-bit IEEE-754 floating point	0	IQ	1	00245CCB 00160000

Data Packet Structure, Information and Packet Class Codes

ODI-2.1

- RULE: An ODI-2.1 device Data Type field SHALL indicate the data type as per the table in the previous slide.
- OBSERVATION: The four MSB of the Data Type field matches the definition and position of the 4-bit Data Type field in VITA 49A. Bits 13 through 19 matches the value in VITA 49 for signal channels equal to or less than 8196.
- RULE: The Vector Size field SHALL indicate the number of signal channels through the formula Vector Size = Signal Channels – 1.
- OBSERVATION: The maximum number of signal channels is 8196.
- RULE: The R/C field SHALL indicate the Real or Complex as per the table in the previous slide
- OBSERVATION: ODI-2 uses the Real subset of R/C field of VITA 49A. Like VITA 49A, ODI-2.1 specifies complex data to be Cartesian, where the I (In-phase) value is followed by the Q (Quadrature) value.

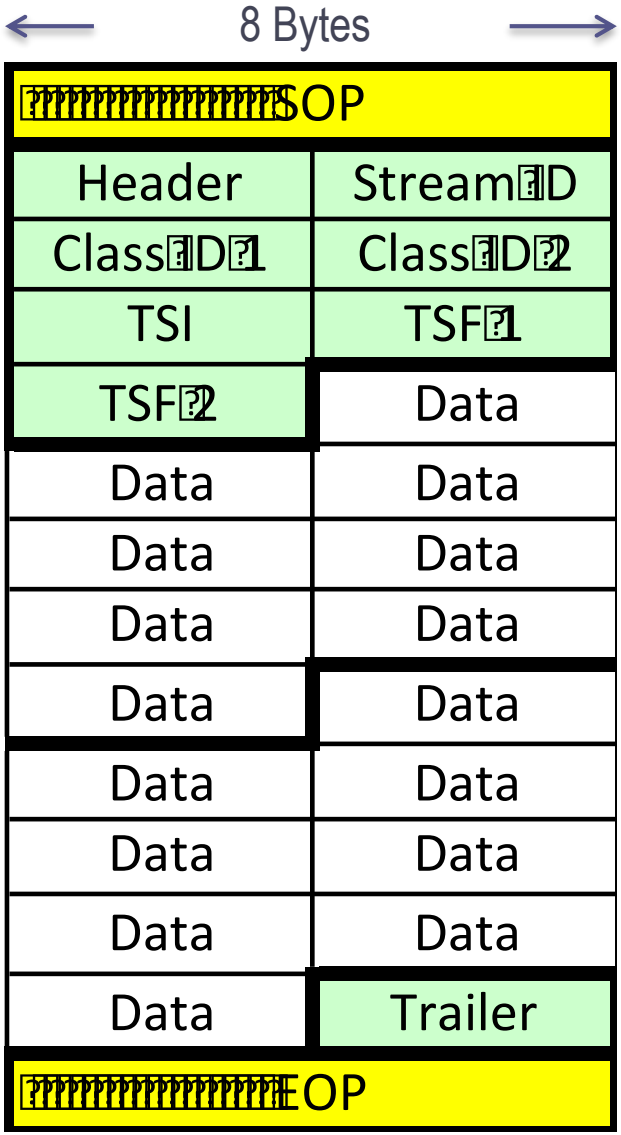
Data Packet Structure, Information and Packet Class Codes - Events

ODI-2.1

- The Evt. (Event) field of the Information Class Code indicates how many bits of each sample (item length indicated in the Data Type field) are dedicated to indicating events, otherwise known as Event Tags. If the Evt. Field is set to zero, then all bits are used to indicate the sample value as previously described. If the Evt. Field is set to a non-zero value, then a certain number of LSBs are replaced with Event bits. The item length (data field length + event bits) always remains as indicated in the Data Type field.
- RULE: The Evt. Field SHALL indicate how many Least Significant Bits of the item sample data are replaced with Event Tag bits, per the table below:

00 = No Event bits
01 = 1 Event bit
10 = 2 Event bits
11 = 4 Event bits

Data Packet Structure, Timestamps



- Timestamp fields remain as specified in ODI-2.

Data Packet Structure, Trailer

- The Trailer remains as specified in ODI-2.

VRT Signal Data Packet Trailer

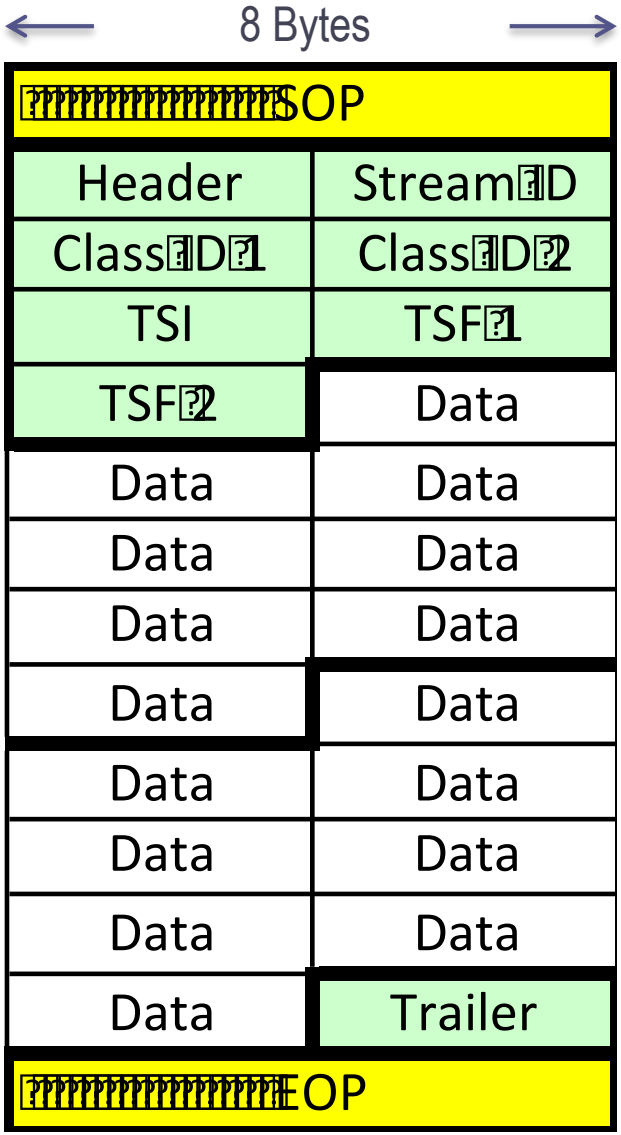
Word	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	Enables												State and Event Indicators												E	Associated Context Packet Count							

Figure 5.1.6-1: VRT Signal Data Packet Trailer

Table 5.1.6-1: Enable and Indicator Bits

Enable Bit Position	Indicator Bit Position	Indicator Name
31	19	Calibrated Time Indicator
30	18	Valid Data Indicator
29	17	Reference Lock Indicator
28	16	AGC/MGC Indicator
27	15	Detected Signal Indicator
26	14	Spectral Inversion Indicator
25	13	Over-range Indicator
24	12	Sample Loss Indicator
23,22	11,10	Sample Frame Indicators, User-Defined
[21..20]	[9..8]	User-Defined Indicators

Data Packet Structure, Data Payload



- The rules for data formats and packing methods follow.

Data Payload- two packing methods

Link efficient: packed most efficiently, word boundaries ignored

Processing efficient: Always start on 32 bit boundaries

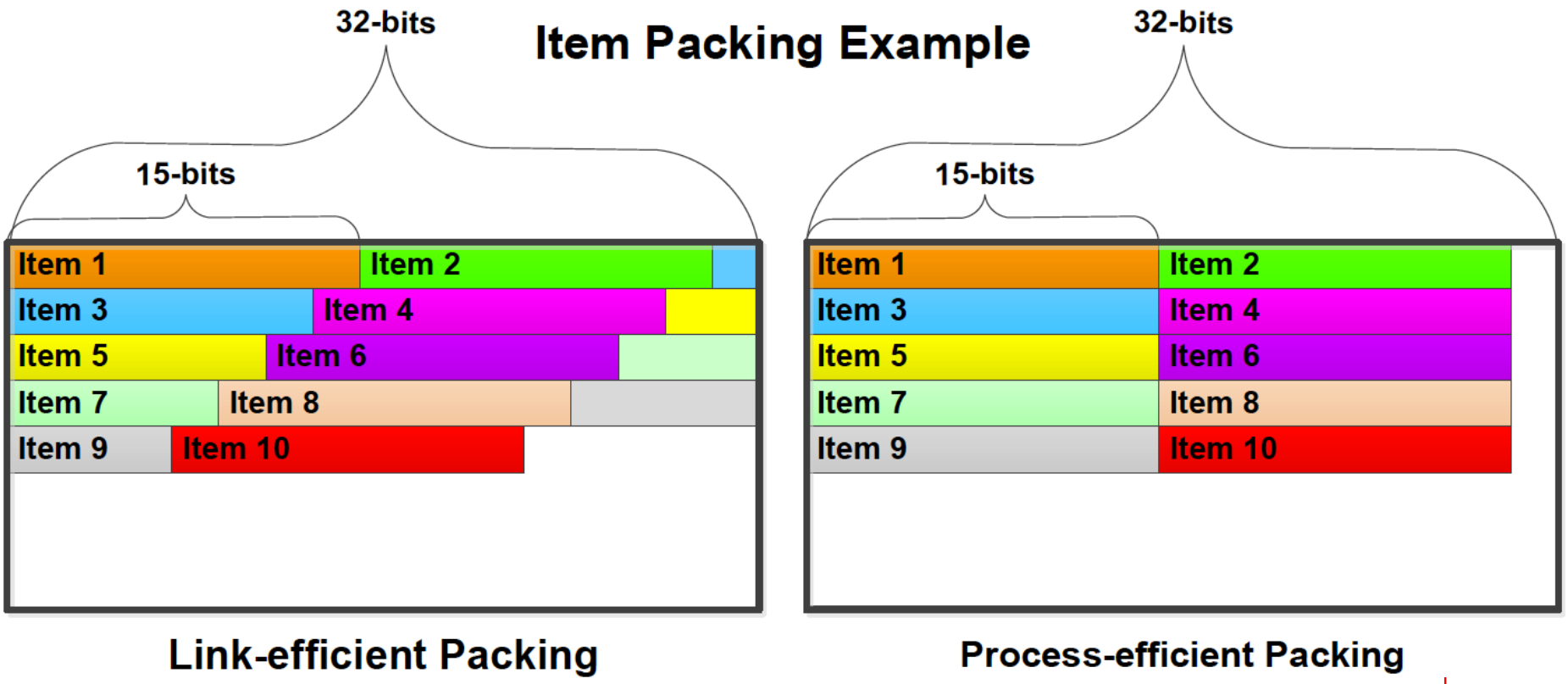
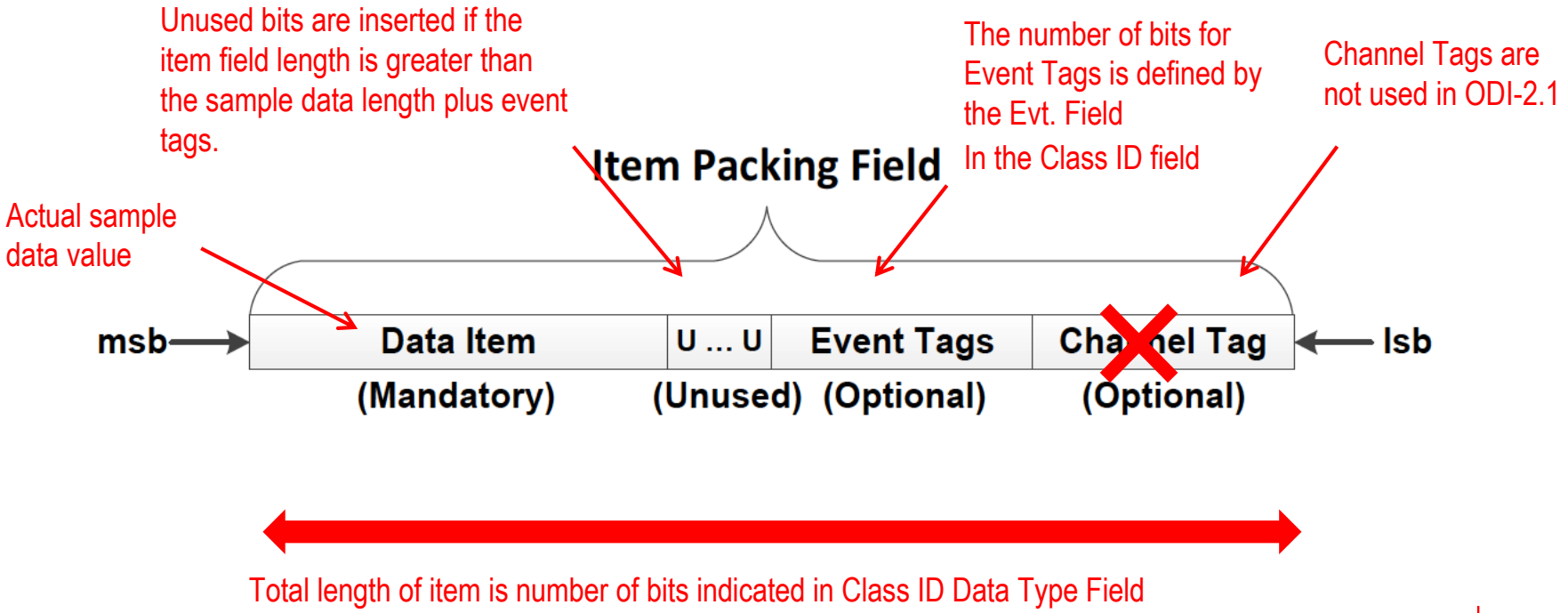


Figure 6.1.1.2-1: 15-bit Item Packing Fields Packed into 32-bit Words

Item Packing Field

VITA 49.2 specifies the item packing field to be a superset of the actual data item. In ODI-2.1, the Data Type field in the Class ID actually indicates the length of the Item Packing Field. This will equal the length of the data item (sample data bits) if there are no Event Tags. Otherwise, the LSBs of the item packing field are repurposed to be event indicators. Below is Figure 6.1.1.1-1 from VITA 49.2. Red text and shapes indicate how each field is deployed in ODI-2.1.



Data Payload Packing – Overview

- ODI-2.1 data packing focuses on the packing of signed fixed binary values from 8 bits of resolution to 16 bits of resolution. Binary values were chosen to deliver the highest sample speed. IQ data is sent as two consecutive binary values, in-phase values first. Data streams may contain data from multiple synchronous channels, but all channels must adopt the same data format (resolution and packing). Multiple channels are packed into the data payload in a round-robin technique, and always in the same channel order.
- For maximum interoperability, ODI-2.1 specifies two mandated formats: 8-bit and 16-bit formats (which are both, processing-efficient and link-efficient packed). The 8-bit format is mandated. The 16-bit format is also mandated if the optical link has the bandwidth to send the 16-bit data.
- For devices that cannot send their full resolution at full speed in 8 or 16-bit mode, ODI-2 allows the option of sending the data as 10, 12, or 14-bit data, with link-efficient processing. These are the preferred link-efficient sample resolutions, even if the samples are naturally of an odd bit-length.
- For devices that have odd bit-length samples, and cannot attain their full speed with any of the even bit-length values, ODI-2.1 allows link-efficient packing of data at 9, 11, 13, or 15-bit lengths.

Data Payload Packing – Round Robin

- RULE: For single channel devices, the data samples within the Data Payload SHALL be placed in order of their time sequence.
- RULE: For multiple channel devices, the data samples SHALL be placed in the same channel order for all points in time.
- RULE: For multiple channel devices, sequential sets of multi-channel data SHALL be placed in order of their time sequence.
- OBSERVATION: The above rules specify a “round robin” packing process where the same sequence of channels values is packed into the Data Payload sequentially with time.
- OBSERVATION: The above technique works, and only works, with synchronous channels.
- RULE: If a device transmits complex signal data from a signal channel, the device SHALL send the value as two consecutive values starting with the in-phase component, followed by the quadrature component.

Data Packing: 8 and 16 bit modes

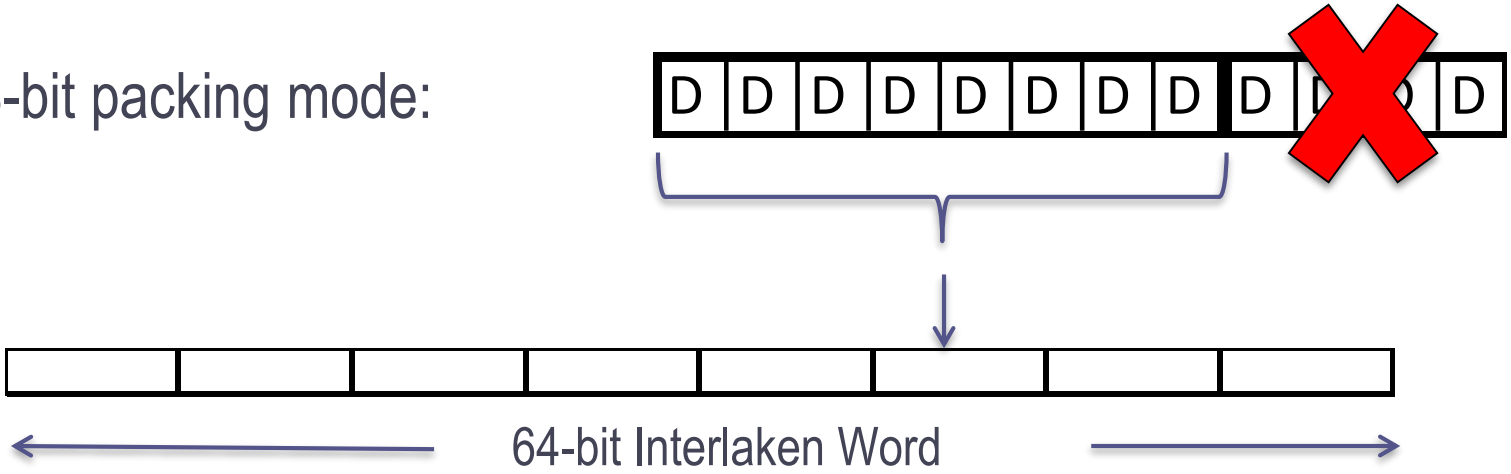
- 8-bit and 16-bit modes are mandatory compatibility modes for all ODI-2.1 devices, if the device can operate at that speed.
- OBSERVATION: 8-bit data and 16-bit data are both, link-efficient packed and processing efficient packed.
- RULE: An ODI-2.1 device SHALL support 8-bit Signed Fixed Point packing mode, indicated by Data Type of 0010 000.
- OBSERVATION: All ODI-2.1 devices that can attain full speed over the ODI link will be able to operate at 8-bit mode at full speed, since it is the fastest of all ODI-2.1 modes.
- RULE: If a device can attain full bandwidth with 16-bit Signed Fixed Point packing THEN the device SHALL support 16-bit Signed Fixed Point packing.
- OBSERVATION: If a device can meet the speed requirement in 16-bit mode, then that mode is required too.
- OBSERVATION: 8-bit mode preserves the speed element of a data stream with 8-bit to 16-bit data, perhaps at the cost of resolution, while 16-bit mode preserves the resolution of the data stream, perhaps at the cost of speed or number of channels.
- RECOMMENDATION: Any device that can't meet the speed requirement in 16-bit mode, SHOULD offer 16-bit modes with reduced capability, such as a reduction in the number of channels.
- OBSERVATION: For data samples between 9 and 15 bits, the data will be concatenated to fit into an 8-bit field, and null data added to fit into a 16-bit field.

Data Packing: 9 to 15 bit modes

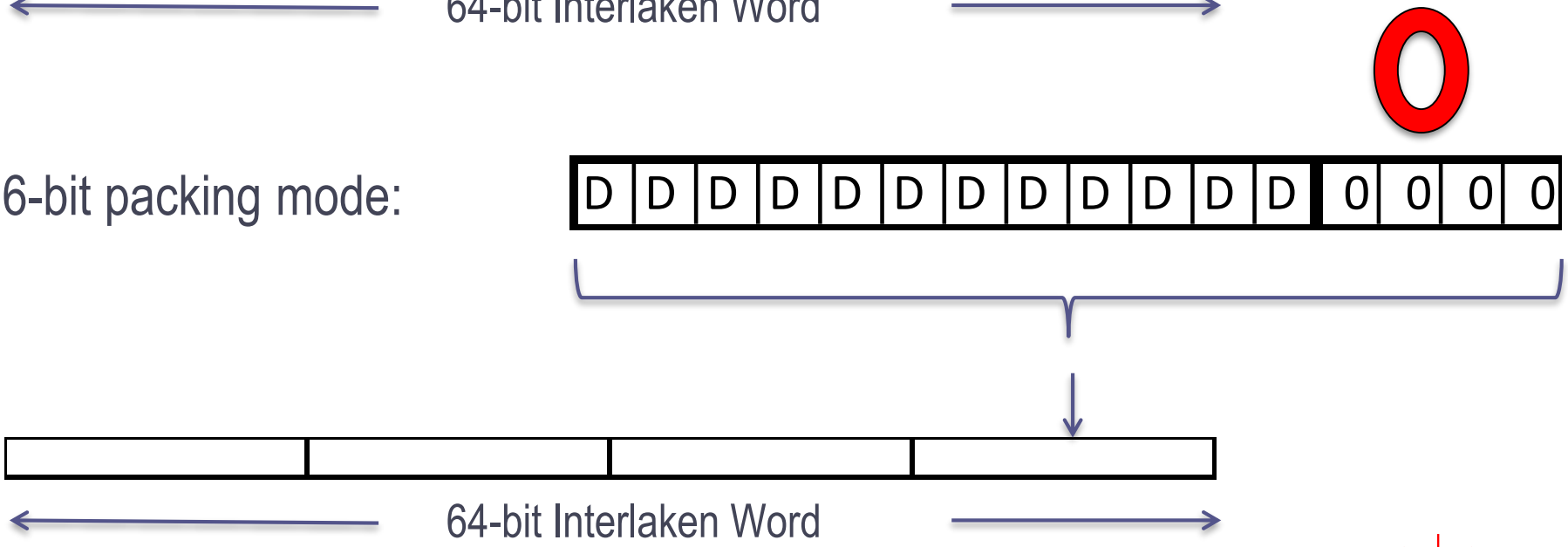
- For devices that cannot operate at their peak resolution and speed at either 8-bit mode or 16-bit mode, ODI-2.1 offers the optional capability to use link-efficient packing of sample lengths between 9 and 15 bits.
- In order to maximize compatibility, the following order of preference of link-efficient packing modes is specified:
  - 8 and 16-bit
  - 10, 12, 14-bit
  - 9, 11, 13, 15-bit
- RULE: If a device cannot achieve its maximum resolution and speed using 8-bit or 16-bit packing, but can achieve maximum resolution and speed using either 10, 12, or 14-bit link-efficient packing, the device SHALL use the 10, 12, or 14-bit link efficient packing mode respectively.
- PERMISSION: If a device cannot achieve its maximum resolution and speed using 8, 10, 12, 14 or 16-bit link efficient packing, but can achieve maximum resolution and speed using either 9, 11, 13, or 15-bit link-efficient packing, the device MAY use the 9, 11, 13, or 15-bit link efficient packing mode respectively.
- OBSERVATION: The rules above essentially mandate using 8 or 16-bit modes if that achieves the speed needed. If not, then try 10, 12 or 14-bit modes. If those don't achieve full speed, then try 9, 11, 13, or 15-bit modes.

Example: 12-bit data

8-bit packing mode:



16-bit packing mode:



Data Packing – other formats

- OBSERVATION: The ODI-2.1 sub-fields in the Information and Packet Class field within the Prologue can indicate data formats other than real or complex Signed Fixed Point data between 8 and 16 bits. These fields allow the expansion of ODI-2.x standards beyond 8 to 16-bit binary data. The other data types are compatible with VITA 49A.

- PERMISSION: ODI-2.1 devices MAY send data consistent with any VITA 49A data and data packing format as defined in Section 6.3 of the VITA 49A specification.

- OBSERVATION: The above rule allows the optional capability of using other VITA 49A defined data packets. What distinguishes ODI-2.1 data formats from VITA 49A is the mandating of 8-bit and 16-bit real and complex data handling, the additional but optional 9-bit through 15-bit link-efficient formats, the optional inclusion of event bits, and the reduction of maximum channel count from 64K channels to 8K channels to allow the additional link-efficient data formats.

Data Packing – Events

- If the Evt. Field indicates that one or more bits of sample data is dedicated to indicating events, then the length of the entire item remains as specified by the Data Type field, but the actual sample data is shortened by the number of event bits, and the event bits are appended to the sample data in the Least Significant Bit position.
- Example. If the Data Type indicates a 16-bit data length, and the Evt. Field indicates 4 bits are dedicated to events, then the actual item field consists of 12 bits of sample data followed by 4 bits of Events, as shown below:

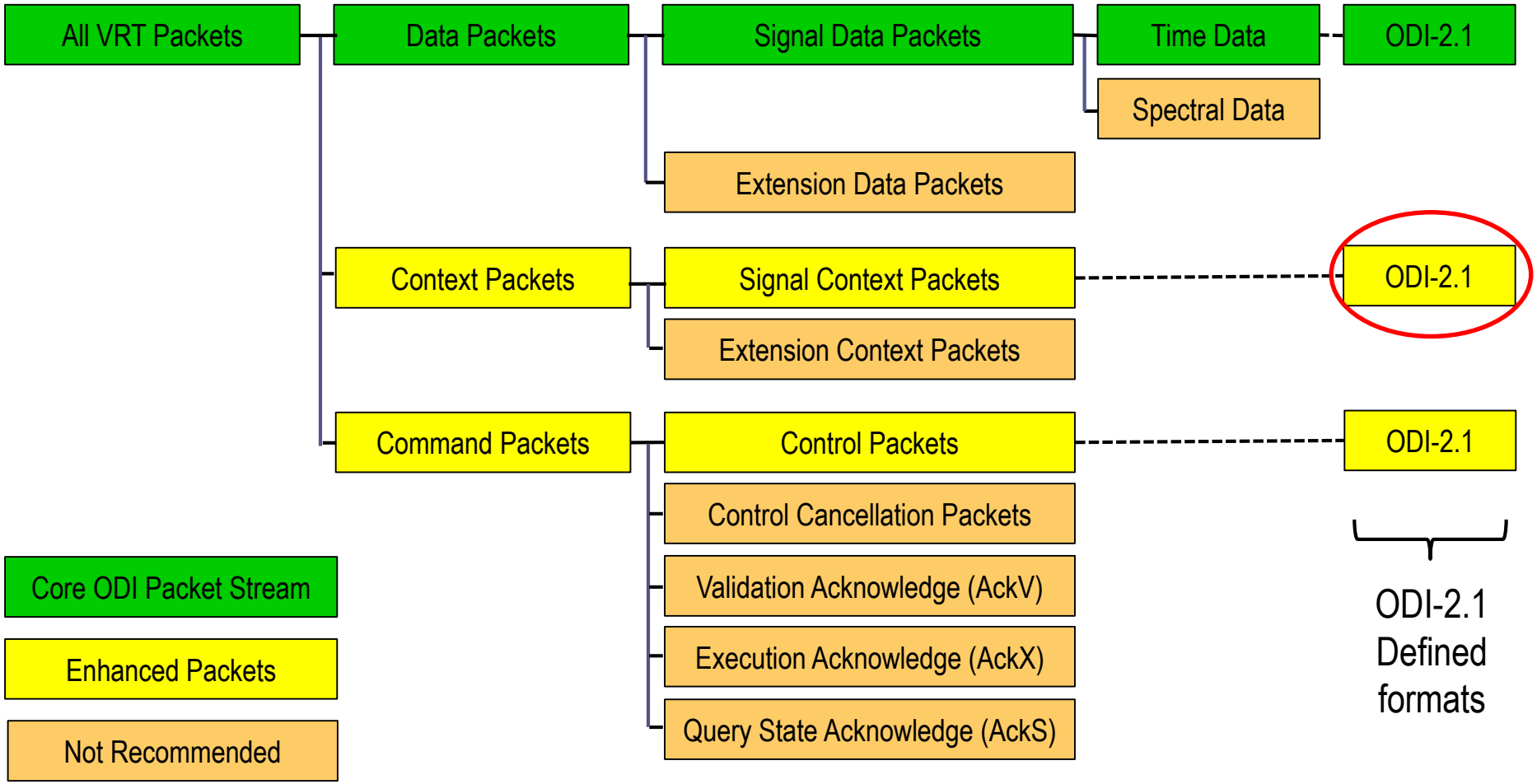
The above figure shows the packing of each item when the Data Type is set to 16-bits and the Evt. Field indicates 4 bits of Event data.

Data Packing – 32 byte constraint

- OBSERVATION: ODI-2 devices are constrained Data Payloads that are a multiple of 32 bytes in length. This rule remains in effect for ODI-2.1 devices.
- OBSERVATION: the Data Payload is equal to the number of channels multiplied by the sample bit length, multiplied by the number of samples per channel in each packet.
- The producer may choose any number of samples per packet, as long as the total packet length is equal to or less than 262,122 bytes.
- OBSERVATION: For any bit-lengths B, 32 samples will fit into B VRT words using link-efficient packing.
- Therefore, for any bit-lengths, 256 samples will fit into 8*B VRT words = B*(32 bytes).
- For N channels, all with 256 samples per channel, the total length = N*B*(32 bytes).
- K sequences for N channels, all with 256 samples per channel, the total length= K*N*B*(32 bytes).
- If N and B are known, the producer chooses a K such that $K*N*B*32 \leq 262{,}112$.
- Equivalently $K \leq 8191/(N*B)$
- Choosing the largest K that satisfies the above will result in the largest packet size, and therefore the highest packet data efficiency.
- OBSERVATION: A value of K can be chosen for any number of channels through 200, and higher channel counts can be supported beyond that, depending on the bit-length and specific number of channels.

ODI-2.1 Context Packet Specifications

ODI-2.1 Context Packet Specifications

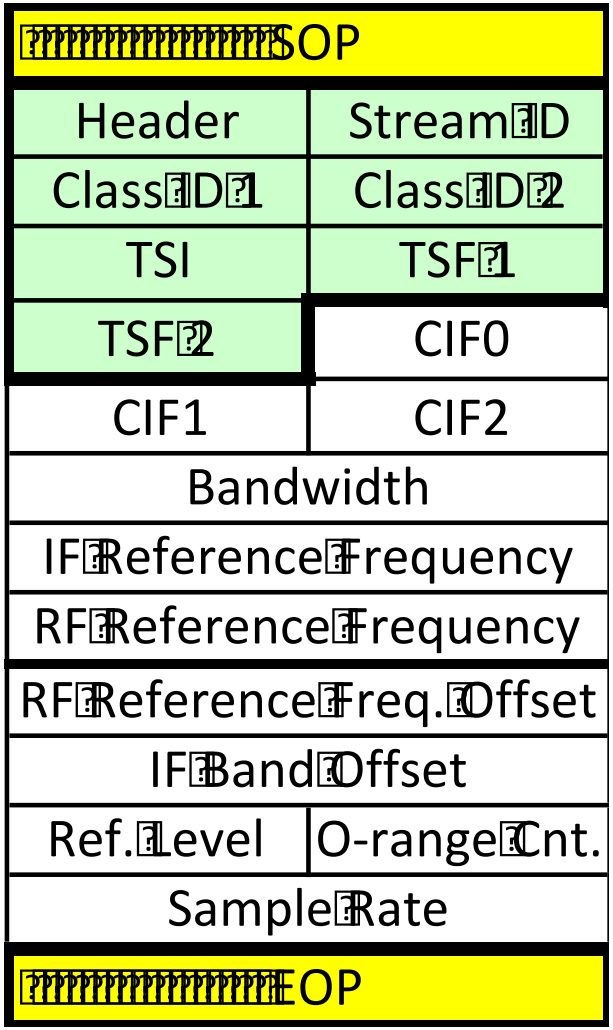


Context Packets

- Context Packets convey metadata about the signal stream.
- ODI-2.1 defines a standard 96-byte Context Packet, shown on the following slide.
- The standard Context Packet is defined with fixed fields to ease the use of FPGAs to handle the Context data.
- As with ODI-2, handling Context Packets is optional capability of ODI-2.1 devices. There is no requirement to do so. A producer is NOT required to generate Context Packets, but MAY do so.
- Context Packets and Command Packets have many similarities. VITA has specified Context Packets as the standard way to report metadata related to a signal, and Command Packets as the standard way to control metadata parameters related to the signal. ODI-2 and ODI-2.1 allow consumers to treat Context Packets as commands, allowing recorded data to be played back. However, if a device can execute Context Packets received, it SHALL also execute Command Packets, the preferred method. The key metadata parameters and fields are designed in ODI-2.1 to be in the same location for ease of FPGA implementation.
- A consumer is NOT required to act on Context Packets received, but MAY do so. As with ODI-2, an ODI-2.1 consumer that receives Context Packets that it does not know how to process is required only to continue normal operation. That is, the reception of Context Packets should not interfere with otherwise normal operation.
- RULE: An ODI-2.1 producer that generates Context Packets SHALL include the Prologue fields specified for ODI-2.1 Context Packets
- RULE: An ODI-2.1 producer that generates Context Packets SHALL include context data fields shown in the following diagram.
- RULE: The context data fields SHALL comply with the requirements of each field as documented in VITA 49.2.

ODI-2.1 Standardized Context Packet

← 8 Bytes → = 1 Interlaken Word

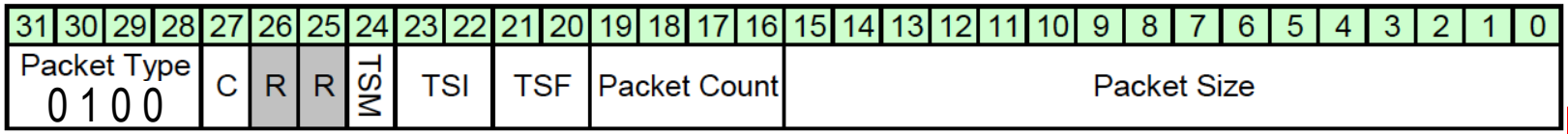


Standard Context Packet is 96 bytes,

Consists of a 32 byte prologue, followed by 64 bytes of context fields.

Context Packet Structure, Header

- The figure below shows the content of the mandatory header for ODI-2.1 Context packets, and is reflective of VITA 49.2 Signal Context Packets.
- Packet Type (28-31): Packet Type SHALL be the value 0100 as shown
- OBSERVATION: The specified Packet Type indicates an Signal Context packet.
- C bit (27) SHALL be set to 1. This indicates a Class ID fields are present
- RR bits (24-25) SHALL be set to 0. These are VITA reserved bits.
- The TSM bit (24) is the TimeStamp Mode bit, indicating whether the TimeStamp in the Context packet is being used to covey timing of Context events with fine or coarse resolution. If TSI is set to 11 (no TimeStamp, but TimeStamp field is present) the TSM bit SHALL be set to 1. Otherwise the TSM bit will be set according to VITA-49.2, Section 7.
- TSI bits (22-23) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Integer field is present. If the device does not support timestamps, then 11 SHALL be used.
- TSF bits (20-21) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Fractional fields are present. If the device does not support timestamps, then 01 SHALL be used.
- When a Context Packet Stream is paired to a Data Packet Stream, the TSI and TSF fields SHALL be the same.
- Packet Count (16-19) is a modulo-16 counter that counts the number of Context packets sent. Bit 16 is the LSB. Packet Count will increment for each packet sent.
- Packet Size (0-15) SHALL be set to 24 (decimal).
- OBSERVATION: Setting Packet Size to 24 accurately matches the number of 4-byte words in the packet.



Context Packet Structure, Stream ID

- Stream ID is an abbreviation for Stream Identifier
- The Stream ID is a 32-bit field, whose value is the same for all data and context packets associated with that stream
- RULE: All ODI-2.1 devices SHALL include a Stream ID field
- RULE: The Stream ID for a Context packet SHALL match the Stream ID for the related Data Packet Stream.
- OBSERVATION: ODI-2 specifies that Data Packet Stream IDs must be programmable by the user. Since related Context packets must share the same Stream ID, they must also be programmable to the same value.
- OBSERVATION: The default Stream ID is 4096, the same as for Data packets.

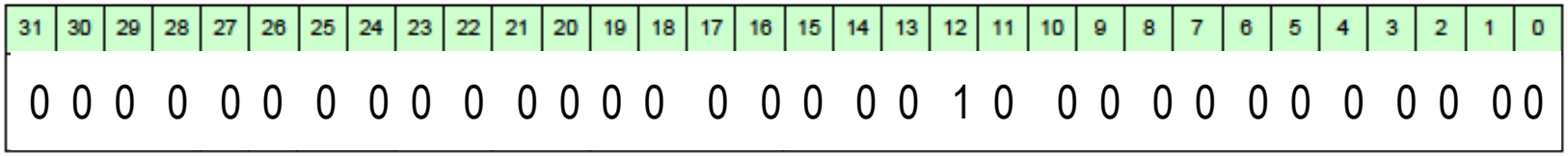


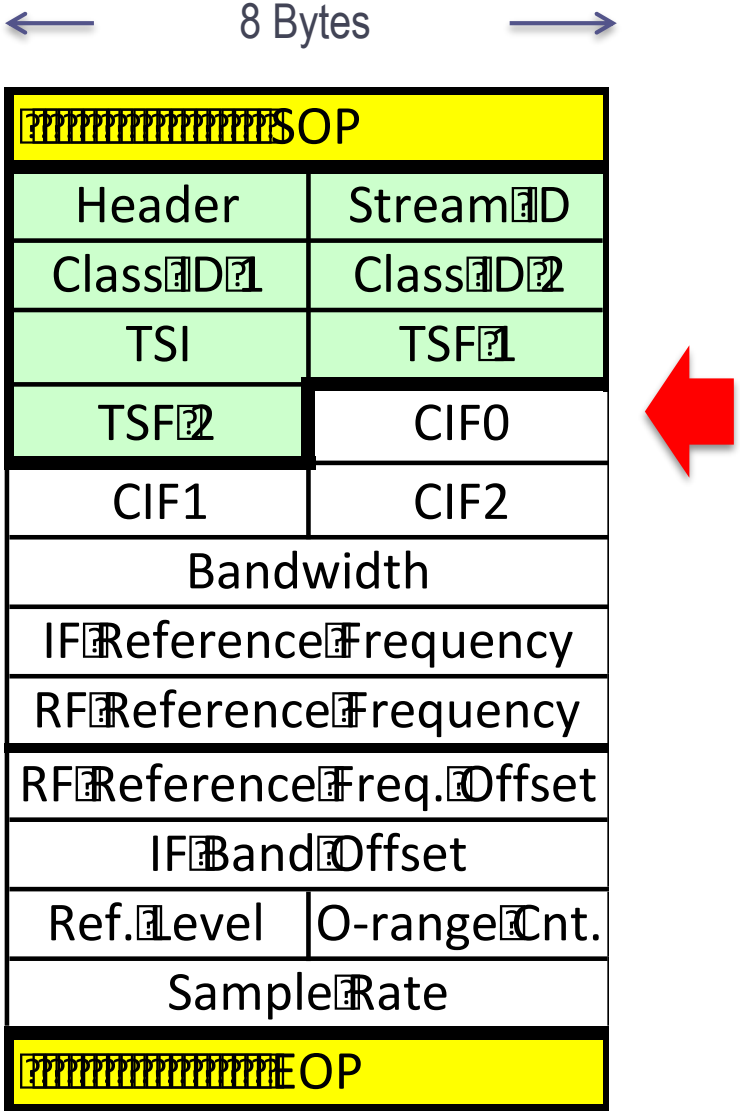
Figure shows Stream ID field configured for Stream ID= 4096

Context Packet Structure, Class ID

- The purpose of Class ID is to identify the Information Class used for the application, and the Packet Class from which each Context Packet was made. ODI-2.1 has a single Context Packet definition, and a single Class ID value.
- RULE: OUI SHALL be set to the AXIe OUI of 2-4-5-C-C-B
- OBSERVATION: This is the same value as for Data Packets.
- RULE: The Information Class Code and Packet Class Code SHALL be set to
  2-0-1-7 / 0-0-1-0 respectively, each digit being a hexadecimal value.
- OBSERVATION: The Information Class and Packet Class Codes are different from those codes in the ODI-2.1 Data Packets, and different than the value for VITA 49A.

Figure 5.1.3-1: Contents of the Class ID Field

Context Packets, Context Indicator Fields



- The Context Indicator Fields indicates which fields follow, and if any data has changed since the last Context Packet.
- OBSERVATION: Except for the Context Field Change Indicator Bit, CIF0 is a fixed value, because the ODI-2.1 fields are fixed definition
- RULE: An ODI-2.1 CIF0 SHALL be set to X-F-6-0-0-0-0-6 Hex, where X=3 when there is no context field change, and X=B when there is a context field change.
- RULE: CIF1 and CIF2 SHALL be set to 0.
- Derivation of the above values is shown on the following slides.

ODI-2.1 Context Indicator Fields

← 8 Bytes →

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CIF
CIF 1	CIF 2
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

Bit Position	Context Indicator Field	
X 31	Context Field Change Indicator	
0 30	Reference Point Identifier	= 3 or B
1 29	Bandwidth	
1 28	IF Reference Frequency	
1 27	RF Reference Frequency	= F
1 26	RF Reference Frequency Offset	
1 25	IF Band Offset	
1 24	Reference Level	
0 23	Gain	= 6
1 22	Over-range Count	
1 21	Sample Rate	
0 20	Timestamp Adjustment	
0 19	Timestamp Calibration Time	= 0
0 18	Temperature	
0 17	Device Identifier	
0 16	State and Event Indicators	
0 15	Data Packet Payload Format	= 0
0 14	Formatted GPS (Global Positioning System) Geolocation	
0 13	Formatted INS (Inertial Navigation System) Geolocation	
0 12	ECEF (Earth-Centered, Earth-Fixed) Ephemeris	
0 11	Relative Ephemeris	= 0
0 10	Ephemeris Reference Identifier	
0 9	GPS ASCII	
0 8	Context Association Lists	
0 7..0	CIF Enable bits	= 0, 6

ODI-2.1 Context Indicator Fields

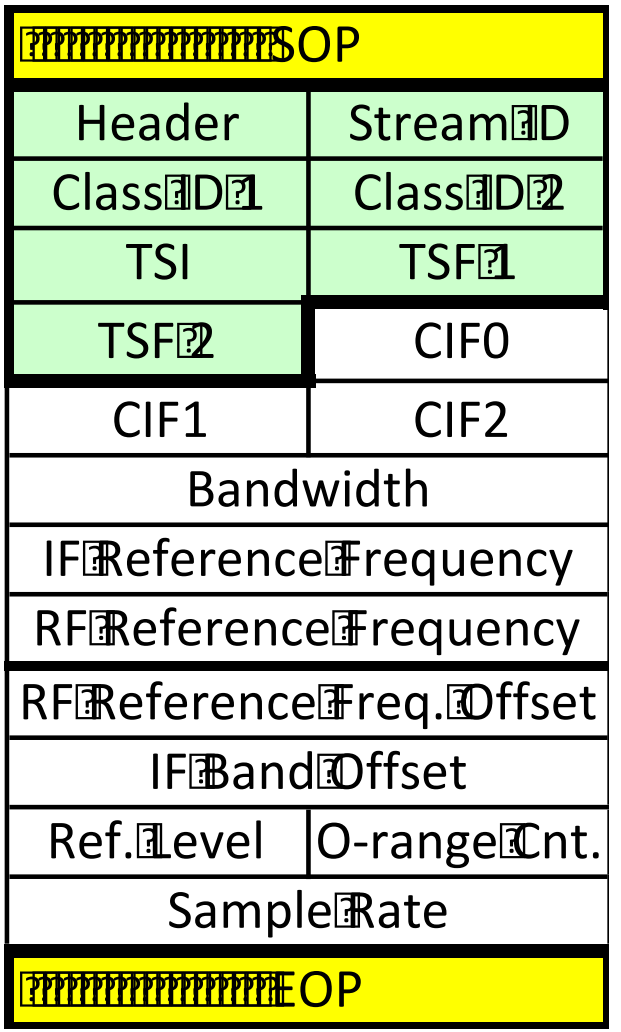
← 8 Bytes →

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CIF
CIF 1	CIF 2
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

0	6	Reserved for CIF expansion
0	5	Reserved for CIF expansion
0	4	Reserved for CIF expansion
0	3	CIF 3 Enable
1	2	CIF 2 Enable
1	1	CIF 1 Enable
0	0	Reserved

		ndicator Field	
		ator	= 3 or B
		ffset	= F
			= 6
		e	= 0
0	17	Device Identifier	
0	16	State and Event Indicator	
0	15	Data Packet Payload Format	
0	14	Formatted GPS (Global Position System) Geolocation	= 0
0	13	Formatted INS (Inertial Navigation System) Geolocation	
0	12	ECEF (Earth-Centered, Earth-Fixed) Ephemeris	
0	11	Relative Ephemeris	
0	10	Ephemeris Reference Identifier	= 0
0	9	GPS ASCII	
0	8	Context Association Lists	
0	7..0	CIF Enable bits	= 0, 6

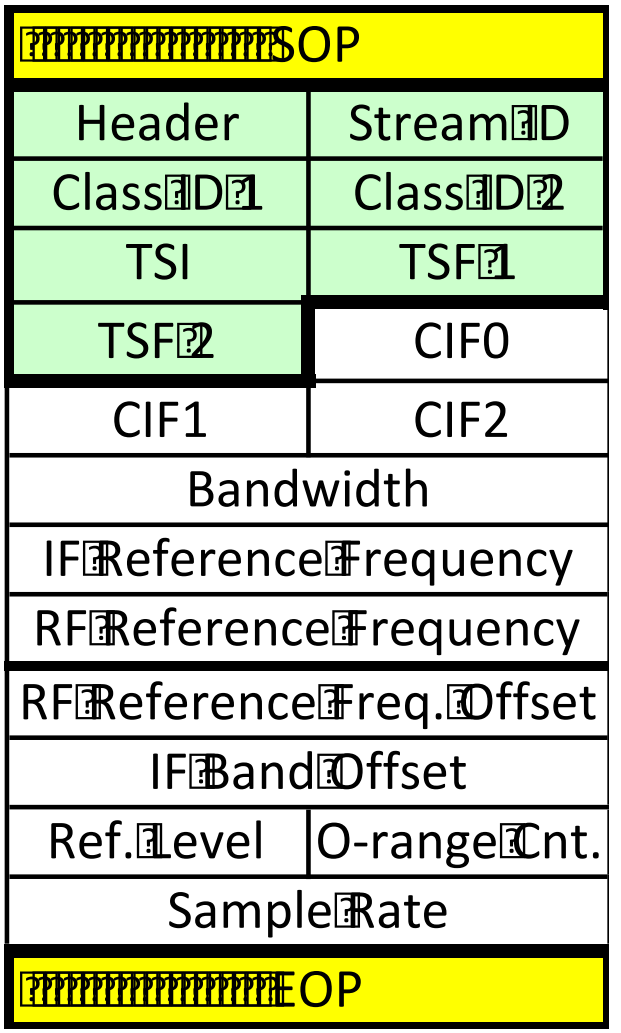
Context Packets:



Bandwidth, Reference Frequencies, and Offsets.

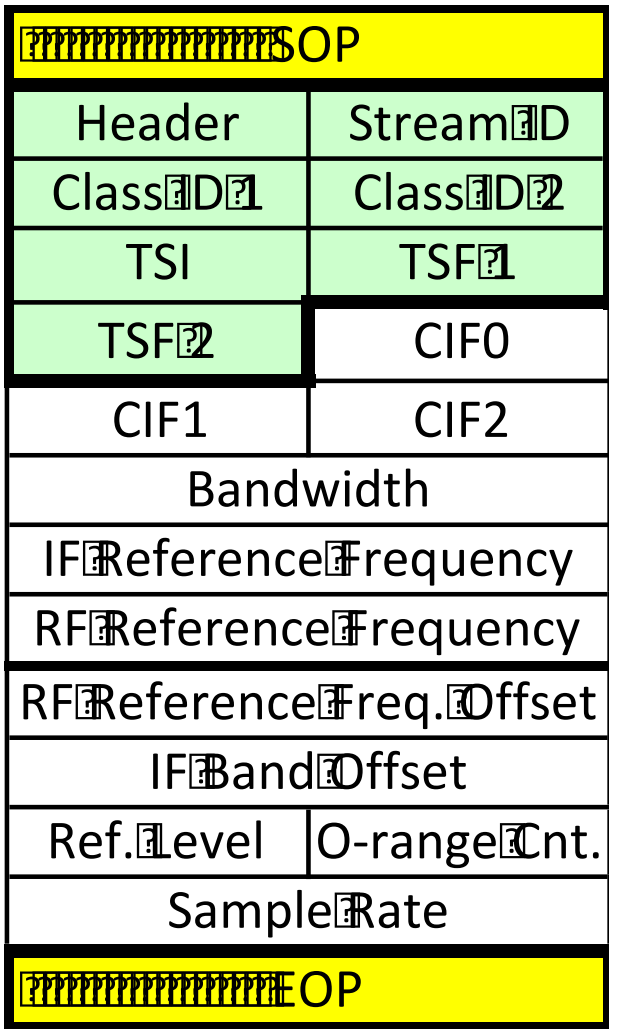
- RULE: The Bandwidth, IF Reference Frequency, RF Reference Frequency, RF Reference Frequency Offset, and IF Band Offset SHALL be set as specified in VITA 49.2 Section 9.5.
- OBSERVATION: A producer that is sending a Context Packet, but doesn't have the actual data for any one of the five fields, will set that field to zero.

Context Packets: Reference Level



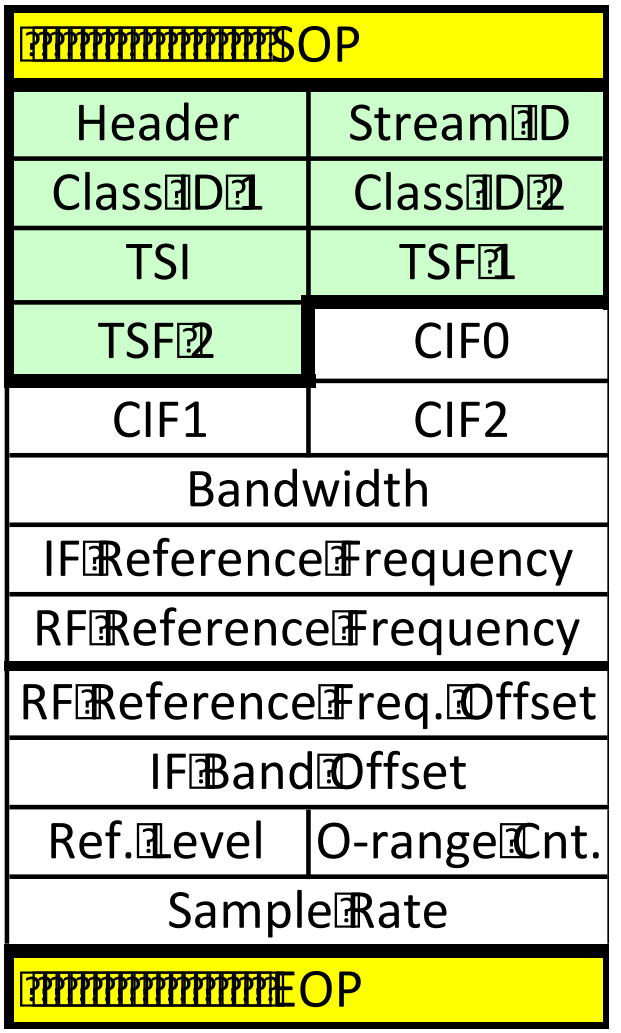
- RULE: The Reference Level field SHALL be set as specified in VITA 49.2 Section 9.5.9.
- OBSERVATION: Since ODI-2.1 specifies signed fixed point binary values within the data packets, Reference Level may be used to normalize the data to absolute values.
- OBSERVATION: Special care should be taken when calculating the Reference Level. The Reference Level is in units of dBm, and is the power into 50 ohms of a Unit-Scale Sinusoid expressed in the associated data stream.

Context Packets: Over-range Count



- The Over-range Count field SHALL be set as specified in VITA 49.2 Section 9.10.6
- If the Over-range Count field is irrelevant, the default value SHALL be 0000.

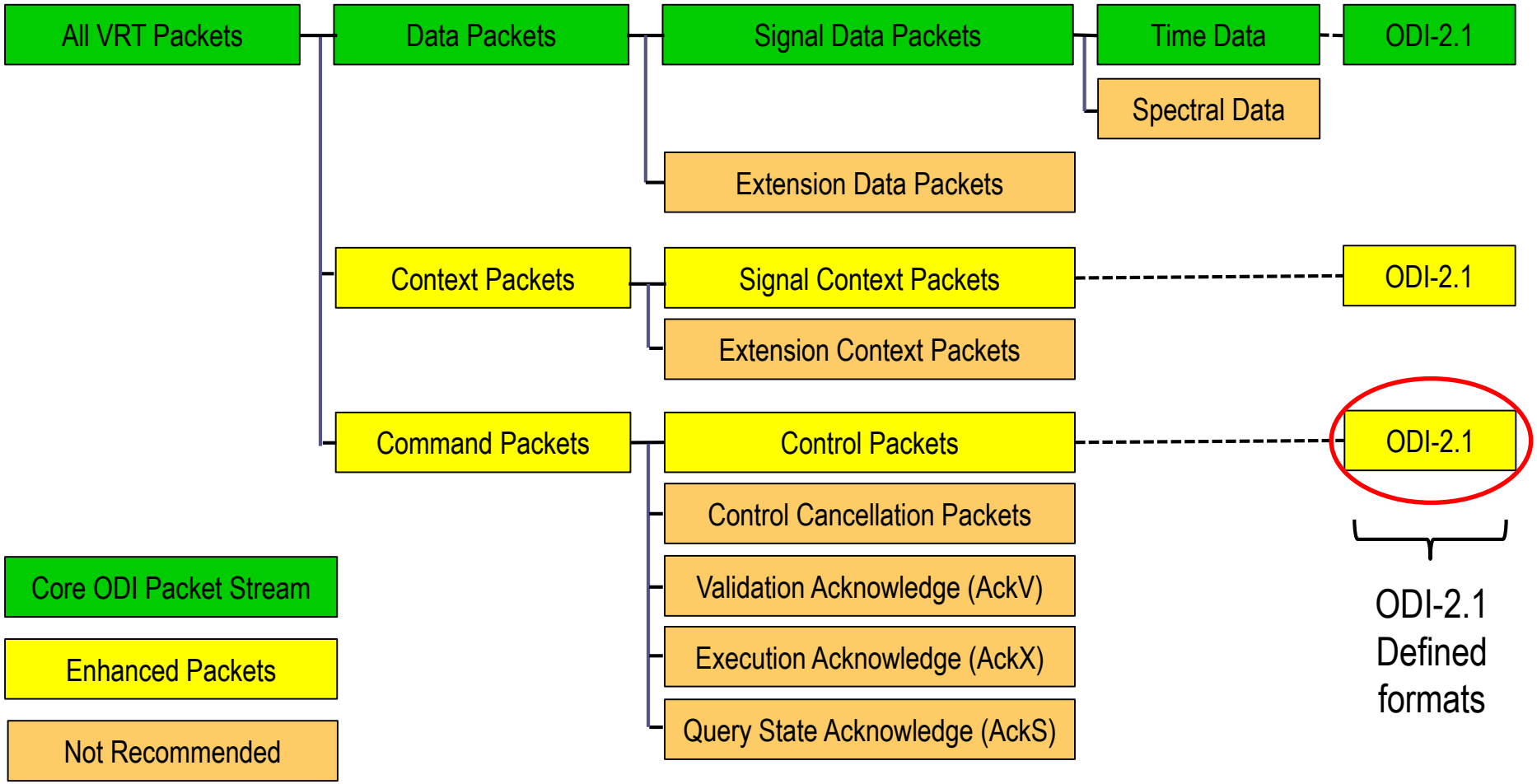
Context Packets: Sample Rate



- The Sample Rate field SHALL be set as specified in VITA 49.2 Section 9.5.12.
- If the Sample Rate field is irrelevant or unknown, the default value SHALL be 0000.

ODI-2.1 Command Packet Specifications

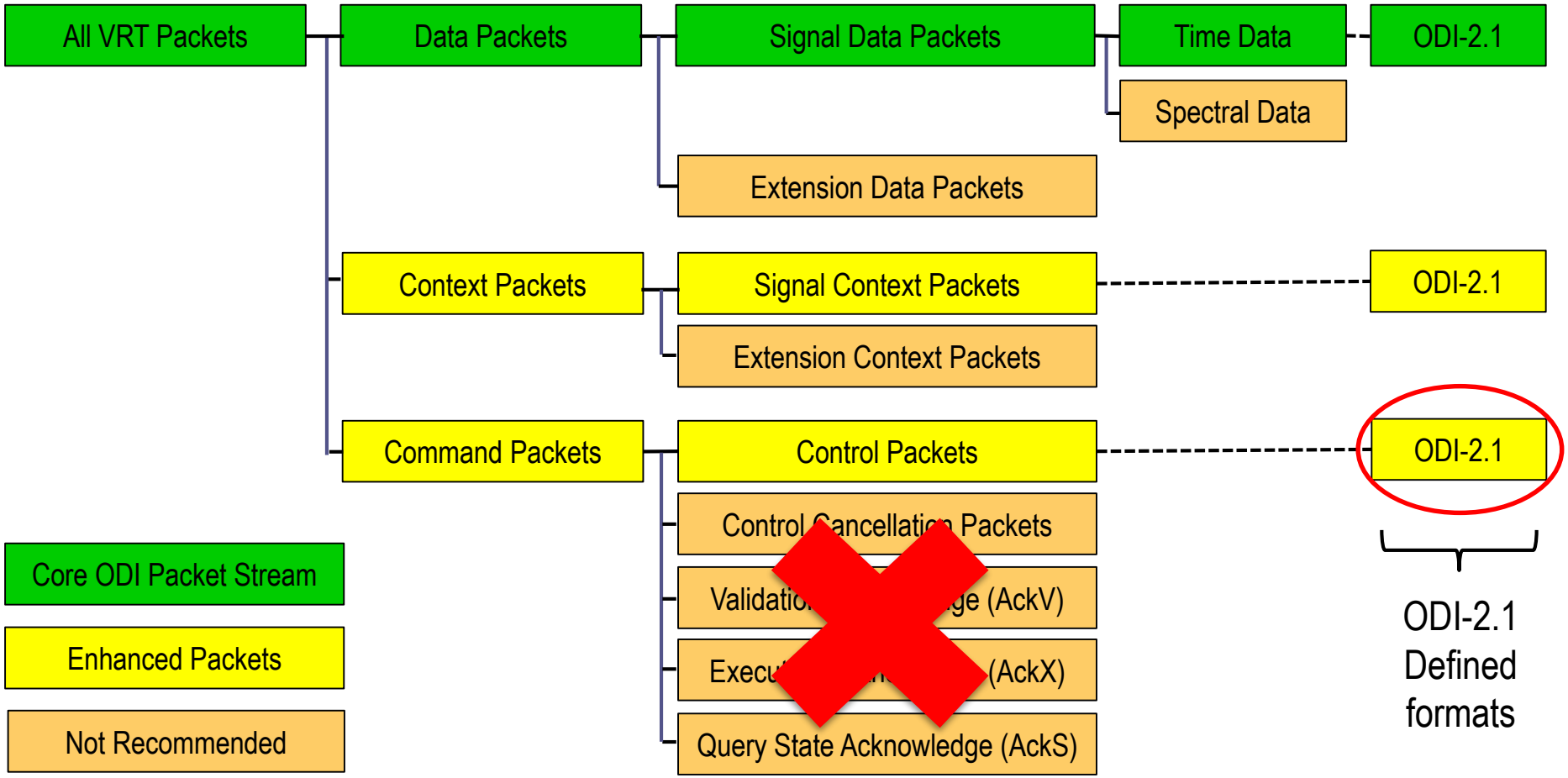
ODI-2.1 Command Packet Specifications



Command Packets -1

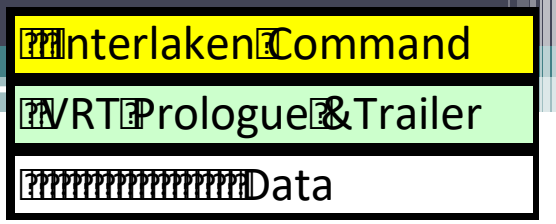
- ODI-2.1 has only one standard Command Packet subtype, the Control Packet. All other Command Packet subtypes are optional.
- Adopting the VRT packet definitions allows the use of Command Packets in addition to Data Packets and Context Packets.
- Handling Command Packets is optional capability of ODI-2 and ODI-2.1 devices. There is no requirement to do so. A producer is NOT required to generate Command Packets, but MAY do so.
- While devices may be controlled through a separate interface to the system controller, command packets enable an in-stream method for sending meta-data to be executed quickly and synchronously with the signal data.
- ODI-2 specifies the general packet structure requirements for Command Packets. ODI-2.1 specifies a standard Control Packet for interoperability.
- Control Packets are analogous to Context Packets in that they convey metadata related to the signal. While Context Packets describe metadata about a digitized or recorded signal, Control Packets enable control of similar parameters to an exciter, such as a signal generator.
- RULE: If an exciter, such as a signal generator, can accept control information over its ODI port, it SHALL be able to do so through Control Packets. It MAY also be controlled, via a software command, to execute Context Packets. This last permission allows a signal generator to execute recorded signals, including the associated Context Packets.
- A consumer is NOT required to act on Command Packets received, but MAY do so. A consumer that receives Command Packets that it does not know how to process is required only to continue normal operation. That is, the reception of Command Packets should not interfere with otherwise normal operation.
- Command Packets have a standard 36 Byte Prologue and no Trailer.
- Command Packets, like other packets, must be a multiple of 32 Bytes in length
- Command Packets MUST comply with the rules in VITA 49.2, Section 8.

ODI-2.1 Command Packet Subtypes



- The only standardized Command Packet subtype in ODI-2.1 is the Control Packet. The other subtypes are not standardized.

Standardized Control Packet



← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CAM
Message ID	CIF0
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

← Interlaken Start of Packet Command

VRT Control Packet Prologue. 36 Bytes.

Similar to VRT Context Prologue, with two additional fields, CAM and Message ID.

Context/Command Fields

Note that all the metadata fields from Bandwidth through Sample Rate are in the same position as Context Packet metadata fields.

← Interlaken End of Packet

Control Packets - Prologue

Interlaken Command
VRT Prologue & Trailer
Data

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CAM
Message ID	CIF0
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

← Interlaken Start of Packet Command

The first 28 bytes of an ODI-2.1 Control Packet are similar to those of a Context Packet.

- Header is defined in subsequent slides
- Stream ID is identical
- Class ID is identical
- TSI and TSF are identical
- CAM and Message ID are defined in subsequent slides.

← Interlaken End of Packet

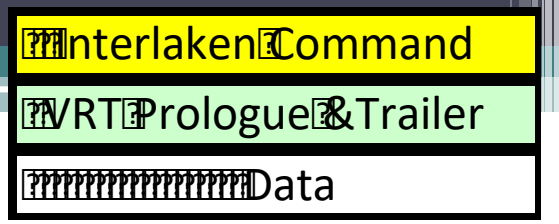
Control Packet Structure, Header

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Packet Type				C	*Indica-tors*			TSI		TSF		Packet Count				Packet Size															
0	1	1	0	C	A	R	L	TSI		TSF		Pkt Count				Packet Size															
				1	0	0	0																								

vita49d2-drawings_20170315.vsd

Figure 8.2-2: Command Packet Header

- Packet Type (28-31): Packet Type SHALL be the value 0110 as shown
- C bit (27) SHALL be set to 1. This indicates a Class ID fields are present
- A bit (26) SHALL be set to 0. This indicates a Control Control Packet.
- L bit (24) SHALL be set to 0 to indicate NOT a Control-Cancellation packet.
- TSI bits (22-23) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Integer field is present. If the device does not support timestamps, then 11 SHALL be used.
- TSF bits (20-21) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Fractional fields are present. If the device does not support timestamps, then 01 SHALL be used.
- When a Command Packet Stream is paired to a Data Packet Stream, the TSI and TSF fields SHALL be the same.
- Packet Count (16-19) is a modulo-16 counter that counts the number of Command packets sent. Bit 16 is the LSB. Packet Count will increment for each packet sent.
- Packet Size (0-15) indicates how many VRT 32-bit (4-Byte) words are present in the entire Command packet, including the mandatory Prologue fields.



Control Packets - Prologue

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CAM
Message ID	CIF0
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

← Interlaken Start of Packet Command

Stream ID, Class ID, TSI, and TSF SHALL be set as in ODI-2.1 Context Packets.

← Interlaken End of Packet

Control Packets – CAM field

Interlaken Command
VRT Prologue & Trailer
Data

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CAM
Message ID	CIF0
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

← Interlaken Start of Packet Command

The CAM field for an ODI-2.1 Control Packet SHALL be set to 0F00 0000.

See subsequent slide for derivation of value.

← Interlaken End of Packet

CAM field ODI-2.1

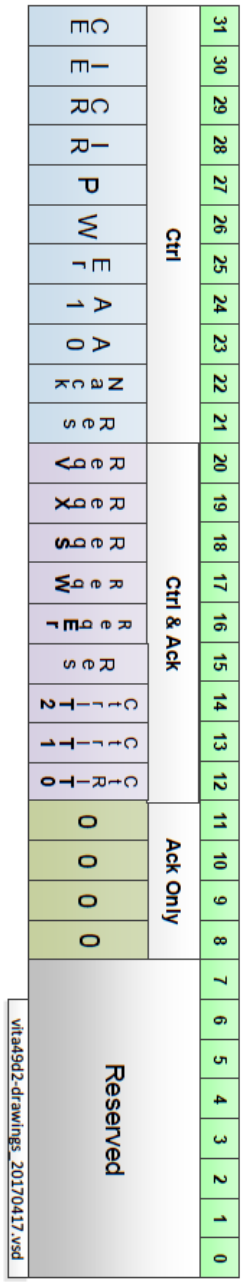


Figure 8.2.1-1 Control Packet: Control/Acknowledge Mode Field

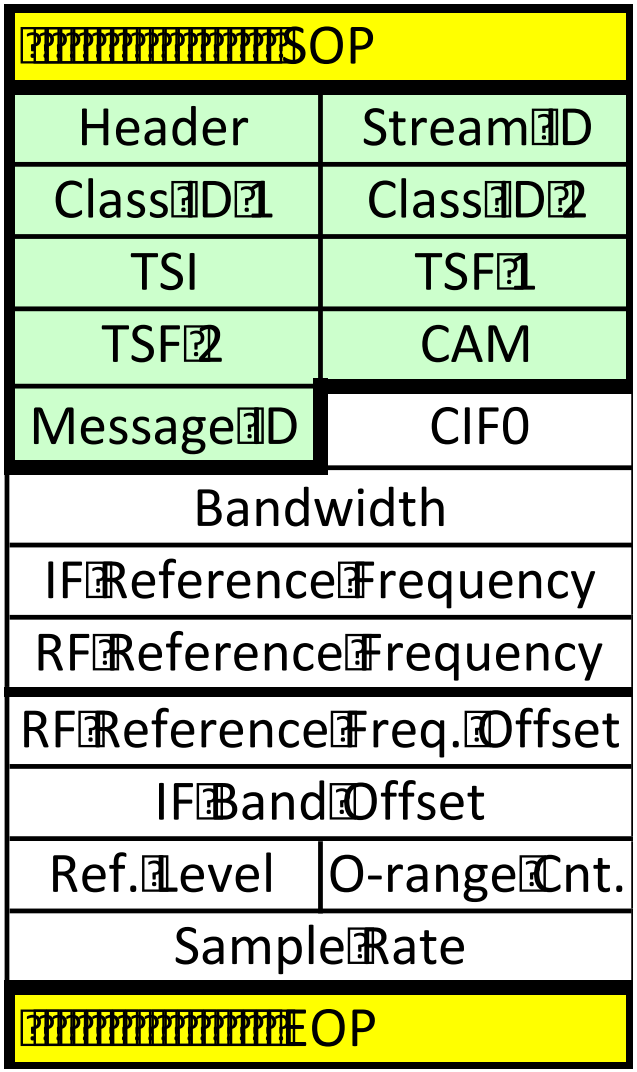
0 = no controllee ID
0 = 32 bit controllee ID (irrelevant)
0 = no controller ID
0 = 32 bit controller ID (irrelevant)
1 = Partial packet implemented. E.g. execute any fields you can
1 = Permit execution of fields with warnings, best effort
1 = Permit execution of fields that generate errors, best effort
1 => Action bits (10) set to execution
0
0 = Irrelevant since Acknowledgement not implemented
0 = Reserved
0 => Bits 16-20 set to 0 as Acknowledgement not implemented
0
0
0
0
0 = Reserved
0 => Execute the control fields with no timestamp constraints
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0

CAM field for ODI-2.1 Control Packet = 0F000000

Interlaken Command
VRT Prologue & Trailer
Data

Control Packet – Message ID

← 8 Bytes → = 1 Interlaken Word



← Interlaken Start of Packet Command

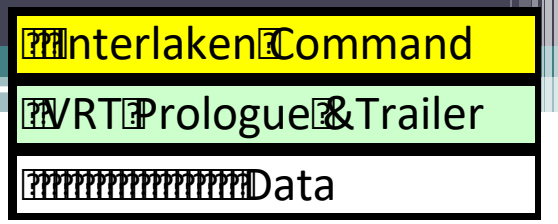
← **Message ID**

The Message ID field of an ODI-2.1 packet will follow those of ODI-2:

RULE: Each new Control Packet SHALL have a unique Message ID.

OBSERVATION: This Rule can be met with a counter that is incremented for each Control Packet.

← Interlaken End of Packet



Control Packet – Metadata

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	CAM
Message ID	CIF0
Bandwidth	
IF Reference Frequency	
RF Reference Frequency	
RF Reference Freq. Offset	
IF Band Offset	
Ref. Level	O-range Cnt.
Sample Rate	
EOP	

← Interlaken Start of Packet Command

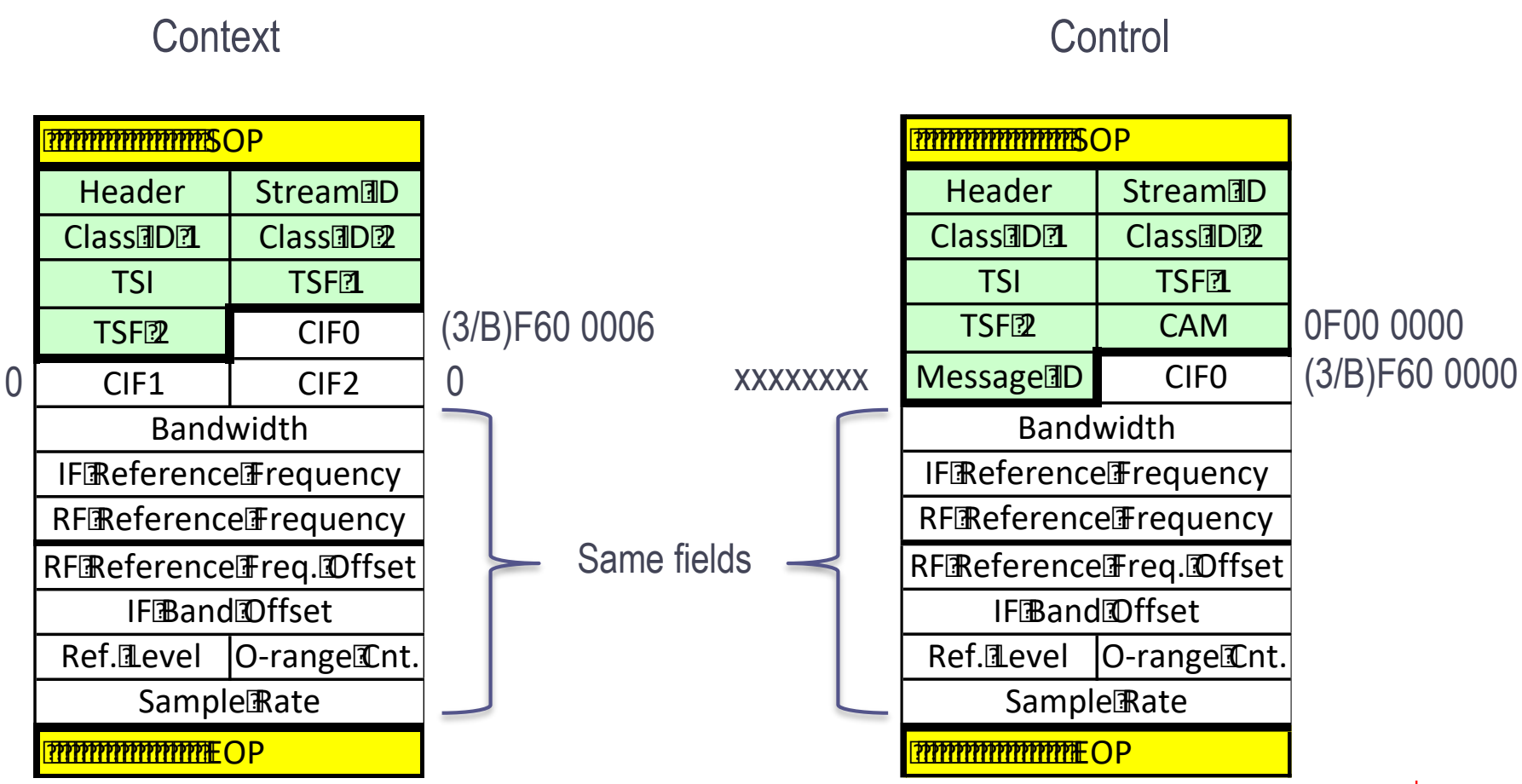
RULE: An ODI-2.1 CIF0 SHALL be set to X-F-6-0-0-0-0-0 Hex, where X=3 when there is no context field change, and X=B when there is a context field change.

Context/Command Fields

Note that all the metadata fields from Bandwidth through Sample Rate are in the same position as Context Packet metadata fields. All rules for Control metadata fields are exactly the same as for Context metadata fields.

← Interlaken End of Packet

Observation: ODI-2.1 Metadata fields are the same for Context and Control Packets



Documentation requirements

- RULE: All ODI-2.1 devices SHALL document the VRT packet structures and classes that they support.
- OBSERVATION: The above rule aligns with the VITA 49.2 rule of documenting all packet structures. Following the VITA rules will meet the above ODI-2.1 rule.
- OBSERVATION: While ODI-2.1 documents the allowable data structures, it does not document the data structures chosen by any one device.
- OBSERVATION: The above rule also compels a vendor to document the use of the Context Packet fields.
- RULE: IF a device supports additional data formats beyond those specified in ODI-2.1, THEN the device SHALL document those formats.
- OBSERVATION: The above rule is also implied by the ODI-2 documentation requirements.