IEEE-ISTO Std 4900-2021: Digital IF Interoperability Standard

Version 1.2.0

Aug 23, 2023

Revision History

Release Level	Release Date	Description
1.0	August 18, 2021	Final v1.0
1.1	August, 2022	First working group cleaned up version v1.1 - Board approved 8.9.2022. Beside other the handling of IPv6 and use of UDP checksum has been clarified
1.2.0	September, 2023	Restructured document for clarity. Added table of deviations from VITA49.2 Added Information Class 0x0002 and Packet Classes 0x0002, 0x0003, 0x0005, and 0x0006. Added Appendices

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1. INTRODUCTION

The data plane interface provides the ability to transmit and receive digitized RF (radio frequency) or IF (intermediate frequency) data respectively as well as corresponding metadata over standard IP networks. This interface is substantially compliant with the VITA 49.2 standards [2], with some deviations as noted in Section 1.5.

Working knowledge of related documents given below is assumed.

1.1 RELATED DOCUMENTS

Industry Standard Documents:

[1] VITA Radio Transport (VRT) Standard, VITA 49.0 – 2015.

[2] VITA Radio Transport (VRT) Standard, VITA 49.2 – 2017.

[3] IEEE 802.1Q-2018. (2018). "IEEE Standard for Local and Metropolitan Area Networks--Bridges and Bridged Networks."

[4] IEEE 802.1ad-2005. (2005). "IEEE Standard for Local and Metropolitan Area Networks - Virtual Bridged Local Area Networks - Amendment 4: Provider Bridges."

[5] J. Postel, "Internet Protocol," RFC 791, IETF, Sep. 1981.
[6] S. Deering and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," RFC 8200, IETF, Jul. 2017.

1.2 DEFINITIONS FOR REQUIREMENTS WORDING

MUST This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.

MUST NOT This phrase, or the phrase "SHALL NOT", mean that the definition is an absolute prohibition of the specification.

SHOULD This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.

SHOULD NOT This phrase, or the phrase "NOT RECOMMENDED" mean that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood, and the case carefully weighed before implementing any behavior described with this label.

MAY This word, or the adjective "OPTIONAL", mean that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.)

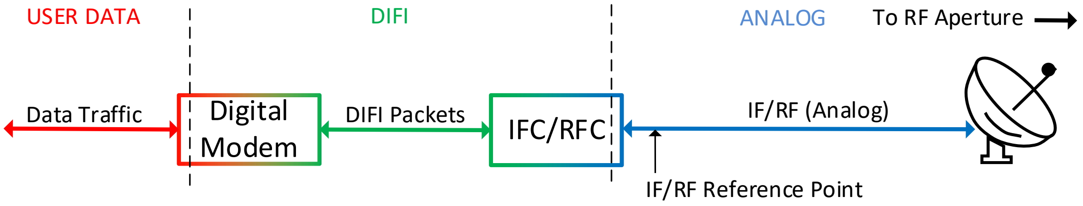
1.3 DIFI STANDARD DEFINITIONS AND CONVENTIONS

The following definitions apply to this document and are illustrated in Figure 1.

DIFI Device	Any hardware, firmware, or software that creates a Source or Sink using the DIFI protocol.
Flow	Transmission or movement of data in the form of packets or a packet stream from Source to Sink.
Full Scale Amplitude	In the context of this document, for an I (Q) sample component with N-bits, the full scale amplitude is 2**(N-1) - 1.
Full Scale Complex Sinusoid	A digital full scale complex sinusoid is one for which the peak magnitude, $\sqrt{I^2 + Q^2}$, is equal to the available full scale amplitude, R, of I or Q taken separately, i.e., the peak magnitude of any full scale complex sinusoid falls on a circle of radius R in the complex IQ plane.
IF Converter	A device that transmutes signals between digital IF and analog IF
Intermediate Frequency (IF) Signal	IF Signal refers to any signal after it has undergone frequency translation. The frequency of this signal may or may not be a typical IF frequency. A zero-IF signal is equal to a complex baseband signal
Information Class	A group of one or more Packet Classes plus packet stream associations that define the structure and information exchange between DIFI devices
Information Stream	A flow of Packet Streams that contain signal data, signal data, metadata and/or control information.
[IP] Socket	IP address and port number
Link Efficient Packing	Link Efficient Packing means that Signal Data Payload is packed in such a way as to maximise efficiency of the ethernet link.
Packet Stream	A flow of packets that carries data from Source to a Sink
Packet Class	A set of rules and structures that define the format and content of a packet
Receive (Rx) Direction	Away from the RF communications aperture or its intended location
Process Efficient Packing	Process Efficient Packing means that Signal Data Payload is packed in such a way as to minimise the process load on the processing hardware, with permission to do this at the expense of link bandwidth.
Reference Point	The point from which data is measured or referenced serves as a common baseline for defining time, frequency, phase, and other related parameters within the Information Classes.

RF Converter	A device that transmutes signals between digital IF and analog RF
Signal Data Packet Sink	Packet StreamSignal destination socket; i.e., a VITA 49.2 packet “consumer”
Signal Data Packet Source	Packet StreamSignal origination socket; i.e., a VITA 49.2 packet “emitter”
Stream Identifier (SID)	The Stream ID is a field within the DIFI header which (i) indicates that a particular Data, Context, or Command Packet is part of a sequence of packets of the same type bearing the same Stream ID, (ii) indicates which Context or Command Packet streams are associated with which Data Packet streams, and (iii) defines a specific location referred to as the SID location, which is used in conjunction with the time stamping.
Transmit (Tx) Direction	Towards the RF communications aperture or its intended location

Duplex Equipment Diagram



Detailed Duplex Equipment Diagram

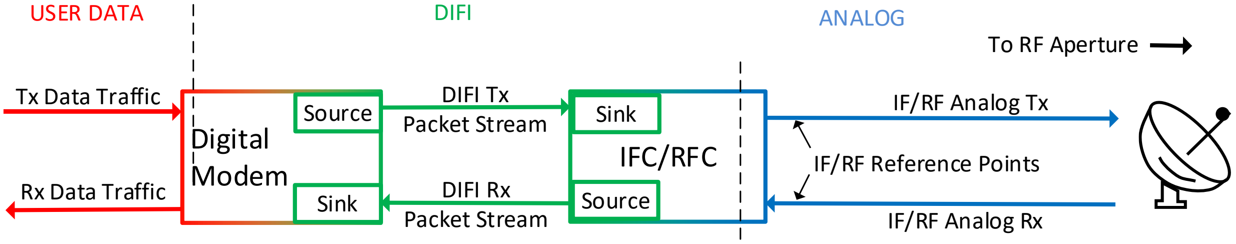


Figure 1.DIFI Standard Conventions

1.4 ABBREVIATIONS & ACRONYMS (INFORMATIVE)

ADC	Analog to Digital Converter
ARP	Address Resolution Protocol
CIF	Control Indicator Field
DAC	Digital to Analog Converter
dBFS	"decibels Full Scale", a measure of power of a sampled signal relative to a full scale sinusoid. The power of a full-scale sinusoid is 0 dBFS.
FPGA	Field-Programmable Gate Array
GPS	Global Positioning System
I	In-phase component of a sinusoid with angle modulation
ICD	Interface Control Document
ID	Identifier
IEEE ISTO	IEEE Industry Standards and Technology Organization
IF	Intermediate Frequency
IFC	IF Converter
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IRIG	Inter-range Instrumentation Group
LAN	Local Area Network
MAC	Media Access Control
Msps	Mega-samples per second
N/A	Not Applicable
NIC	Network Interface Controller
NTP	Network Time Protocol
OUI	Organizationally Unique Identifier
POSIX	Portable Operating System Interface
Q	Quadrature component of a sinusoid with angle modulation
RF	Radio Frequency
TSF	Timestamp Fractional
TSI	Timestamp Integer
TSM	Timestamp Mode
UDP	User Datagram Protocol
UTC	Coordinated Universal Time
VLAN	Virtual LAN
VRL	VITA Radio Link Protocol
VRT	VITA Radio Transport

1.5 DEVIATIONS FROM VITA 49.2

While the DIFI Standard is based on VITA 49.2, there are deviations, some of which are indicated as follows:

Reference Level Field	The DIFI Standard breaks this up into two sub-fields. • Mandatory bits 15-0 follows VITA 49.2 • Optional bits 31-16 convey RMS data sample amplitude in dBFS (decibels WRT full scale) where "full scale" is defined in section 1.3

2. DATA PLANE IMPLEMENTATION

The data plane is where the digital RF or IF data and its corresponding metadata are formed into packets for transmission.

The VITA 49.2 specification [2] provides many options for packing Digital IF data. This flexibility requires that an additional layer of documentation be provided to explain a manufacturer's implementation of the standard.

The IEEE-ISTO Std 4900-2021: Digital IF Interoperability Standard has two independent data plane flows as shown in Figure 2:

1) RF/IF-input to IP-network output (receive) and

2) IP-network input to RF/IF-output (transmit).

The following sections detail the Information Classes and Packet Classes used by this Standard, per VITA 49.2 requirements. Section 3 describes the Information Classes supporting various use cases. Illustrations of example applications of the Information Classes to use cases is provided in Appendices. Section 4 describes the Packet Classes used by the Information Classes, including Data, Context, and Command packet formats. Note that VITA 49.2 trailers and VRL framing are not currently used for any data flows.

This Standard provides strict definitions of which fields are included in Data, Context, and Command packets and their meanings, so as to maximize interoperability.

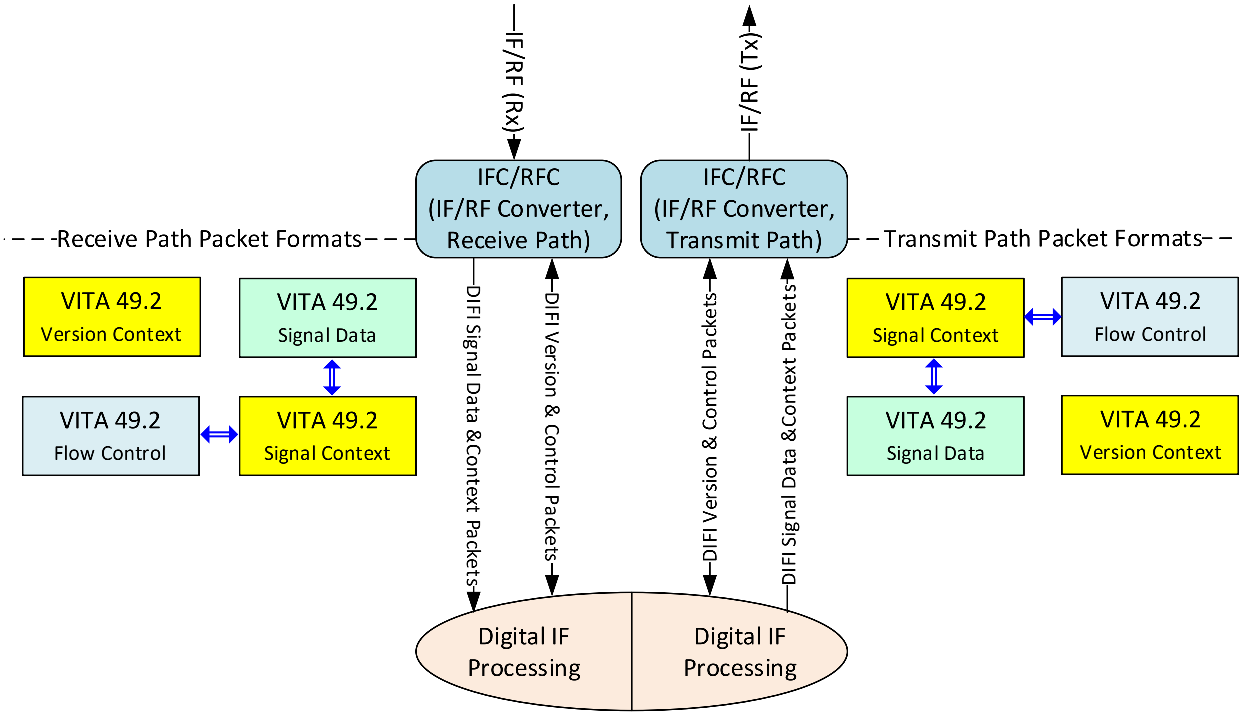


Figure 2. Data Plane Packet Formats

In Figure 2, the transmit direction is shown on the right half of the diagram, receive direction on the left. Streams that are associated with one another are connected by blue double-headed arrows. Although not indicated in the diagram, streams may also flow between Digital IF Processing blocks, examples of which include Digital IF modems and Digital IF Combiners and Dividers. Examples of detailed flows appear in the Appendix.

2.1 PROTOCOL OVERVIEW

The DIFI protocol is used to support DIFI applications, which use DIFI to support IP transport of their application content in the form of DIFI packets. To support DIFI applications, the DIFI protocol layer contains three different types of packets:

1) Context Packets
2) Signal Data Packets
3) Command Packets

Figure 3 provides an overview of the DIFI protocol stack. The DIFI protocol layer is based on IP/UDP using Ethernet as the physical transport layer.

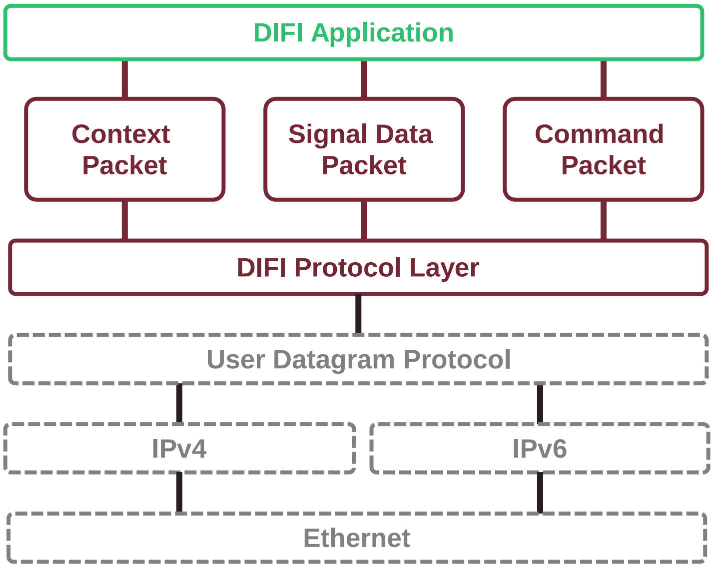


Figure 3. DIFI Protocol Stack

Figure 4 provides an overview of the packets at each protocol layer.

Requirements for Ethernet as well as IP and UDP to integrate DIFI are given in the following sub-sections. This is followed by the definition of the DIFI protocol layer.

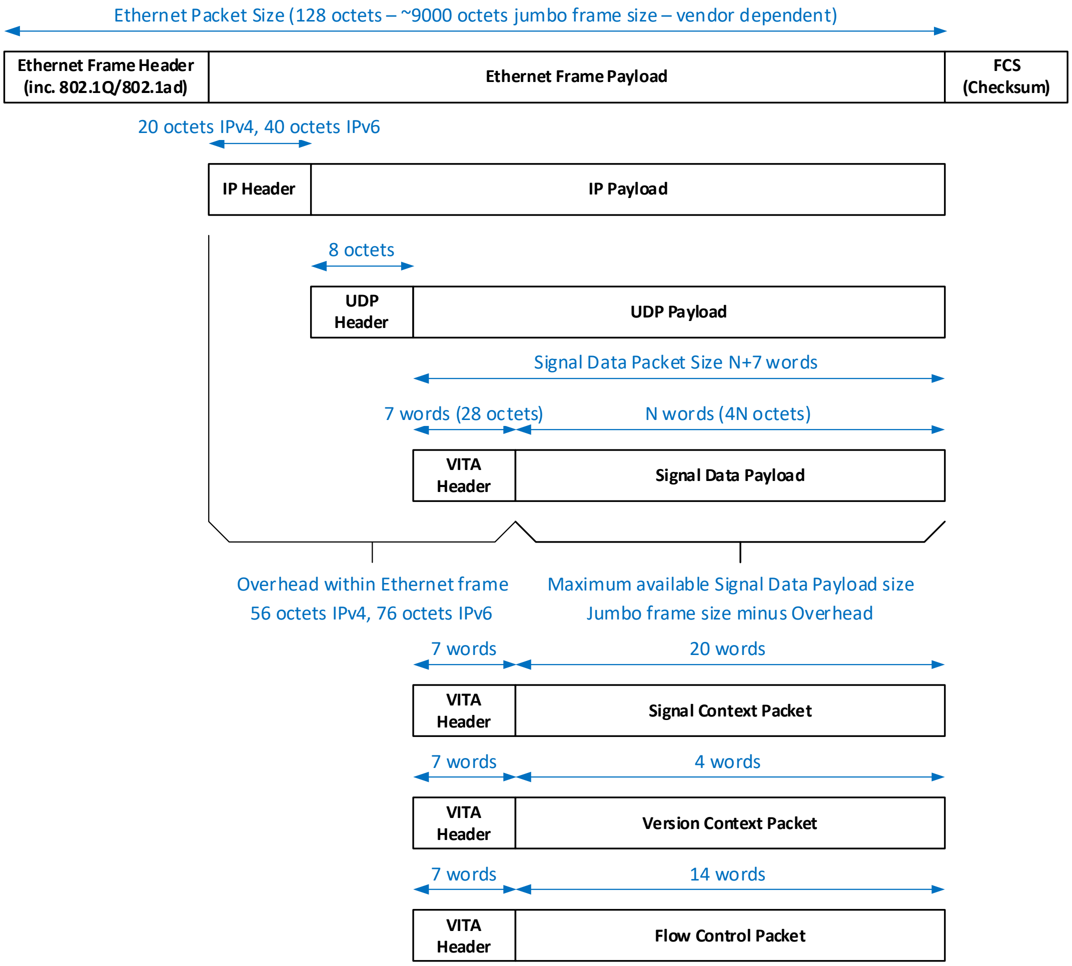


Figure 4. DIFI Protocol Stack – Packets

The total Ethernet packet size for Signal Data Packets varies based on the number and size of the data samples in the payload.

There is a fixed overhead within the Ethernet Frame which comprises:

IP Header (20 octets for IPv4, 40 octets (minimum) for IPv6),

UDP header (8 octets)

VITA header (28 octets)

The Ethernet frame payload is adjustable from 128 octets to 9000 octets.

The Signal Data Payload size is discussed in greater detail near the end of sections 4.1.1 and 4.1.2

2.1.1 Ethernet

DIFI packets shall be contained in standard 802.3 Ethernet frames and support the following extensions:

- Jumbo frames with maximum transmission unit of 9000 bytes
- 802.1Q (VLAN) and 802.1ad (QinQ)

A DIFI end point shall have at least one Ethernet MAC address.

2.1.2 IP

DIFI packets shall be contained in either standard IPv4 frames (RFC 791) or IPv6 frames (RFC 8200). For a given DIFI stream, the source IP address shall be the same for both the context and the data packets.

2.1.2.1 Ipv4 Fragmentation

IPv4 fragmentation shall not be supported.

2.1.2.2 Ipv6 Extension Headers

DIFI shall support the presence of IPv6 extension headers. However, implementations may ignore the content of the extension headers, which may be present. Implementations shall process the payload of IPv6 packets, regardless.

2.1.3 UDP

Each DIFI packet shall be contained in a standard UDP datagram.

It should be noted that UDP checksums are mandatory to comply with IPv6 but optional for IPv4. The DIFI standard does not levy any further requirements. If used, checksums shall be valid for the appropriate packet transport type.

The data payload of the UDP datagram contains either a DIFI context packet, a DIFI control packet, or a DIFI data packet.

3. INFORMATION CLASSES[1]

A DIFI Information Class is a structure consisting of one or more Packet Classes. Packet Classes that are defined for the DIFI standard are described in detail in Section 4.
Within the DIFI standard, an Information Stream conveys various types of user information from one point in a system to another. An Information Stream is composed of Packet Streams, which may convey signal data, metadata describing signal data, and control information. Each such Packet Stream within the Information Stream conforms to one of the defined Packet Classes.

The description of the structure of an Information Stream is called an Information Class. The Information Class defines which Packet Classes are included in the Information Class, and the purpose of each. More specifically, there are eight components to an Information Class. These components encompass every aspect of the Information Stream. In addition to specifying the included Packet Classes and their purposes within the Information Stream, the Information Class also specifies several other details of the Information Stream. The eight components are:

1. Class Name and Code
2. Information Stream Purpose
3. Names of included VRT Packet Streams
4. Purpose of each included Packet Stream
5. Packet Classes
6. Packet Stream Details
7. Reference Points
8. Packet Stream Associations

Individual Packet Classes may be invoked by multiple Information Classes, and therefore those are detailed out separately in Section 4 of this Standard.

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[1] Section 3.6 of VITA 49.2 describes the purpose and requirements of an Information Class in detail.

3.1 Information Class 0x0000, Basic Data Plane

The Basic Data Plane Information Class defined in Table 2 is the original DIFI Standard's Information Class for conveying signal data and the corresponding metadata. It uses Real Time (picoseconds) for its Fractional Seconds Timestamp field and contains only data and metadata (Context) packets, with no Command Packet Stream defined for this Information Class.

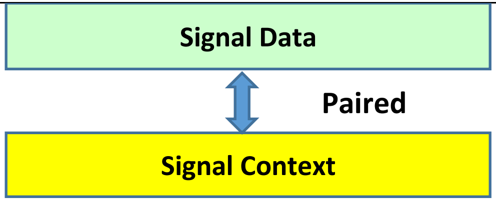
	Information Class Component	**Information Class Component Specification**
1	Class Name, Code	"Basic Data Plane", Class Code 0 (0x0000)
2	Information Stream Purpose	"To convey digitized I and Q samples, with all control and reference configuration information communicated in advance or using non-VRT streams"
3	Packet Stream Names	1. Signal Data 2. Signal Context
4	Packet Stream Purposes	1. Convey signal data as IQ samples 2. Convey data stream context information
5	Packet Classes	1. Standard Flow Signal Data (Packet Class 0x0000) 2. Standard Flow Signal Context (Packet Class 0x0001)
6	Packet Stream Details	1. Data Packet size is not restricted, subject to: • link-efficient packing (bit padding not permitted) • maximum Ethernet packet size of 9000 bytes The packet rate is as needed to support the sample rate at the selected packet size. 2. Context packets are required and must be issued upon change of field content, or upon a user-determined periodicity, whichever comes first.
7	Context/Control Reference Points	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
8	Packet Stream Associations	

Table 1. Information Class 0x0000, Basic Data Plane

3.2 INFORMATION CLASS 0X0001, VERSION FLOW

The Version Flow Information Class is defined in Table 2. This class contains only a Context Packet Class and can be used either for conveying information regarding which version of the DIFI Standard is being used or to convey timestamp information from a Packet Stream Sink to a Packet Stream Source. Users who have an application requiring a DIFI Device Sink to emit timestamped packets for synchronization purposes should use Information Classes 0x0002 or 0x0003.

	Information Class Component	**Information Class Component Specification**
1	Class Name, Code	"Version Flow", Class Code 1 (0x0001)
2	Information Stream Purpose	"To convey type and version information and convey precise time of day for software applications that require synchronization of the stream source to the stream sink."
3	Packet Stream Names	1. Version Flow Signal Context Packet
4	Packet Stream Purposes	1. Convey type and version information 2. Convey time of day information
5	Packet Classes	1. Version Flow Signal Context (Packet Class 0x0004)
6	Packet Stream Details	1. Packet size is 11 words. 2. Context packets may be issued at any rate from zero (off) to one hundred packets per second.
7	Context/Control Reference Points	Reference Point field is not included, reference is to the SID.
8	Packet Stream Associations	No associations

Table 2. Information Class 0x0001, Version Flow

3.3 INFORMATION CLASS 0X0002, DATA PLANE PLUS FLOW CONTROL

The Data Plane Plus Flow Control Information Class provides a fully featured approach to synchronize the sample rate and timestamp of a Packet Stream Source to that of a Packet Stream sink beyond what Information Class 0x0000 provides. It uses Command Packets, which can be emitted by a Packet Stream sink, but can share a Stream ID with a Packet Stream emitted by a different device in the system. The Command Packet Class includes Control Packets and Acknowledge Packets. This Information Class uses only Control Packets. While this initial use case has the Packet Stream sink emitting these Control Packets, and the Packet Stream Source consuming them, this Information Class permits any device in the system to emit the Control Packets (referred to as the “Controller”) and any device or devices to consume the Control Packets (referred to as the “Controllee”).

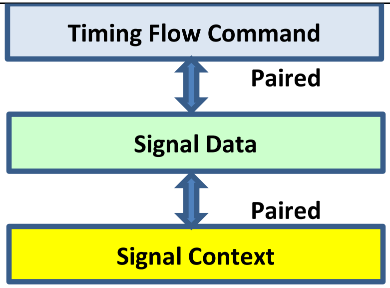
	Information Class Component	Information Class Component Specification
1	Class Name, Code	"Data Plane plus Flow Control", Class Code 2 (0x0002)
2	Information Stream Purpose	"To convey digitized I and Q samples in either the transmit direction or the receive direction, with all control and reference configuration information communicated in advance or using non-DIFI streams, except for the inclusion of 'Flow Control' Command Packets intended to convey timing information for configurations in which a Data Stream sink device is the reference for the Sample Rate timing."
3	Packet Stream Names	1. Signal Data 2. Signal Context 3. Timing Flow Control
4	Packet Stream Purposes	1. Convey signal data as IQ samples 2. Convey data stream context information 3. Convey timing information to permit the data source device to synchronize to the data sink device sample rate
5	Packet Classes	1. Sample Count Signal Data (Packet Class 0x0002) 2. Sample Count Signal Context (Packet Class 0x0003) 3. Sample Count Timing Flow Control (Packet Class 0x0005)
6	Packet Stream Details	1. Data Packet size is not restricted, subject to: • link-efficient packing • maximum Ethernet packet size of 9000 bytes The packet rate is as needed to support the sample rate at the selected packet size. 2. Context packets issued upon change of field content, or upon a user-determined periodicity, whichever comes first. 3. Flow Control Packets are issued at a uniform, user-determined rate of no more than one thousand per second.
7	Context/Control Reference Points	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
8	Packet Stream Associations	

Table 3. Information Class 0x0002 Data Plane Plus Flow Control

3.4 Information Class 0x0003, Data Plane plus Flow Control, Real Time TSF

Information Class 0x0003 is identical to 0x0002 except for using real time (picoseconds) for the Fractional Seconds Timestamp (rather than Sample Count used in 0x0002).

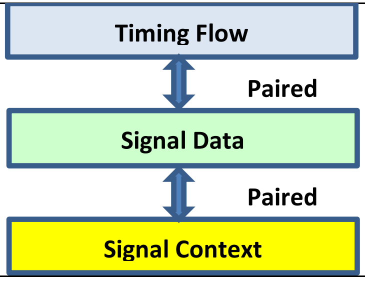
	Information Class Component	**Information Class Component Specification**
1	Class Name, Code	"Data Plane plus Flow Control packets, Real Time TSF", Class Code 3 (0x0003)
2	Information Stream Purpose	"To convey digitized I and Q samples in either the transmit direction or the receive direction, with all control and reference configuration information communicated in advance or using non-VRT streams, except for the inclusion of 'Flow Control' Command Packets intended to convey timing information for configurations in which a Data Stream sink device is the reference for the Sample Rate timing."
3	Packet Stream Names	1. Signal Data 2. Signal Context 3. Timing Flow Control
4	Packet Stream Purposes	1. Convey signal data as IQ samples 2. Convey data stream context information 3. Convey timing information to permit the data source device to synchronize to the data sink device sample rate
5	Packet Classes	1. Standard Flow Signal Data (Packet Class 0x0000) 2. Standard Flow Signal Context (Packet Class 0x0001) 3. Real Time TSF Timing Flow Control (Packet Class 0x0006)
6	Packet Stream Details	1. Data Packet size is not restricted, subject to: • link-efficient packing (bit padding permitted on final word in payload) • maximum Ethernet packet size of 9000 bytes The packet rate is as needed to support the sample rate at the selected packet size. 2. Context packets issued upon change of field content, or upon a user-determined periodicity, whichever comes first. 3. Flow Control Packets are issued at a uniform, user-determined rate of no more than one thousand per second.
7	Context/Control Reference Points	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
8	Packet Stream Associations	

Table 4. Information Class 0x0003 Data Plane plus Flow Control packets, Real Time TSF

4. PACKET CLASSES

DIFI defines three categories of Packet Types, each having a specific purpose, aimed at the overall goal of interoperability.

- Data Packets are defined and constructed to help ensure standardization of signal data transport.
- Context Packets are defined and constructed to help ensure standardization of the transport of metadata describing the sampled signal data, e.g., sample rate and bit depth.
- Command Packets, which include Control and Acknowledge Packets, are used to provide and acknowledge device settings and support control of timing.

A Packet Class defines the structure and function for packets belonging to one of the above Packet Types. A Packet Class is used in one or more places in an architecture to create Packet Streams. A Packet Stream is a sequence of packets of the same Packet Class that serves a particular purpose described by the Information Class that incorporates the Packet Stream. Information Classes are described in Section 3 of this Standard.

4.1 DATA PACKET CLASSES

The Standard presently supports two Data Packet Classes:

- 0x0000, Standard Flow Signal Data
- 0x0002, Sample Count Signal Flow Data

These packet classes are nearly identical, except for the Fractional Seconds Timestamp (TSF), which is Real Time (picoseconds) for Class 0x0000 and Sample Count for 0x0002. Certain conventions apply to all Data Packet Classes unless explicitly stated otherwise:

- The Organizationally Unique Identifier field shall contain the DIFI OUI, 0x6A621E.
- The SID location shall be at the point of generation of digital samples in the receive direction and at the point of consumption of digital samples in the transmit direction (see Appendix 5.1 for more details).

4.1.1 Packet Class 0x0000, Standard Flow Signal Data Packet

<table>
<tr><td colspan="3">Signal Data Packet Class</td></tr>
<tr><td colspan="3">Class Name: "Standard Flow Signal Data," Code 0x0000</td></tr>
<tr><td colspan="3">Packet Stream Purpose: "To convey digitized I and Q samples."</td></tr>
<tr><td colspan="3">Packet Header</td></tr>
<tr><th>Parameter</th><th>Selected Options</th><th>Comments</th></tr>
<tr><td>Packet Type</td><td>Signal Data Packet with Stream ID</td><td>Conveys digitized I and Q samples</td></tr>
<tr><td>Packet Size</td><td>Variable, user selected</td><td>Seven words in prologue plus “N” 32-bit words in the data payload</td></tr>
<tr><td>Stream Identifier</td><td>Yes</td><td>Selected by user at run time</td></tr>
<tr><td>Class ID</td><td>Present</td><td>OUI is 0x6A621E
Packet Class Code is 0x0000</td></tr>
<tr><td>Integer Timestamp</td><td>Present</td><td>May be UTC, POSIX, or GPS as specified in Packet Header</td></tr>
<tr><td>Fractional Seconds Timestamp</td><td>Real-time, picoseconds</td><td>May be locked to an external reference</td></tr>
<tr><td colspan="3">Packet Payload</td></tr>
<tr><th>Parameter</th><th>Selected Options</th><th>Comments</th></tr>
<tr><td>Packing Method</td><td>Link Efficient</td><td>Data items are packed into 32-bit words. See Figure B-44 of VITA-49.2 for an illustration. Bit padding in the final word of the data payload is not permitted in Information Class 0x0000.</td></tr>
<tr><td>Data Item Size</td><td>Variable, user selected</td><td>Individual I and Q sample components may be 4 to 16 bits in length (I and Q pairs 8 to 32 bits in length)</td></tr>
<tr><td>Item Packing Field Size</td><td>Variable, twice the Data Item Size</td><td></td></tr>
<tr><td>Real/Complex Type</td><td>Complex Cartesian</td><td></td></tr>
<tr><td>Data Item Format</td><td>Signed Integer (V49.2 Signed Fixed-Point with code 00000, implying no fractional component)</td><td></td></tr>
<tr><td>Sample-repeating/Channel-repeating</td><td>N/A</td><td rowspan="2">No repeating of any kind</td></tr>
<tr><td>Repeat Count</td><td>0</td></tr>
<tr><td colspan="3">Packet Trailer</td></tr>
<tr><td colspan="3">(Not Used)</td></tr>
</table>

Table 5. Packet Class 0x0000, Standard Flow Signal Data

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>Word #</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td colspan="2">TSI</td><td>1</td><td>0</td><td colspan="4">Seq Num</td><td colspan="16">Packet Size = N+7 words</td><td>1</td></tr>
<tr><td colspan="32">Stream Identifier (assigned at run time)</td><td>2</td></tr>
<tr><td colspan="5">pad bit count</td><td>0</td><td>0</td><td>0</td><td colspan="24">24-Bit DIFI CID (0x6A621E)</td><td>3</td></tr>
<tr><td colspan="16">Information Class (number of incorporating class)</td><td colspan="16">Packet Class = 0x0000</td><td>4</td></tr>
<tr><td colspan="32">Integer Seconds Timestamp (per TSI field)</td><td>5</td></tr>
<tr><td colspan="32" rowspan="2">Fractional Seconds Timestamp (Real Time [picoseconds])</td><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="32" rowspan="12">Signal Data Payload
(Complex Cartesian, 4 - 16-bit signed integers, N 32-bit words,
bit padding per Information Class documentation)</td><td>8</td></tr>
<tr><td></td></tr>
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<tr><td></td></tr>
<tr><td></td></tr>
<tr><td>N+6</td></tr>
<tr><td>N+7</td></tr>
</table>

Table 6. Packet Class 0x0000 Format, Standard Flow Signal Data

- **Word 1: Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x1 which indicates a Data packet with a stream ID.
  - **Bit 27: Class ID Indicator**

    This bit must be set to 1, which indicates the optional Class Identifier field is included.
  - **Bit 26: Trailer Indicator**

    This bit must be set to 0, which indicates no packet trailer is used.
  - **Bit 25: VITA49.0 Indicator**

    This bit must be set to 0 which indicates the Data Packet should not be interpreted as the prior VITA49.0 standard.
  - **Bit 24: VITA 49.2 Spectrum / Time**
  - This must be set to 0x0 which indicates the packet contains time data (rather than spectrum data which is not currently supported by this standard). This maintains compliance with VITA 49.2 specification [2] Rule 6.3.1-2.
  - **Bits 23-22: Timestamp Integer**

    The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 7.

TSI Code	Meaning
00	The TSI code 00 is not allowed*
01	Coordinated Universal Time (UTC) which has an epoch of Jan 1, 1970, and includes leap seconds
10	GPS which has an epoch of Jan 6, 1980 but does not include leap seconds
11	POSIX time which has an epoch of Jan 1, 1970 but does not include leap seconds

*The value is not allowed because the timestamp field *is* used in the data packets

Table 7. The Meaning of the TSI Codes

- **Bits 21-20: Timestamp Fractional**

  Bits 21-20 are set to 0x2 to indicate that this packet uses Real Time (picoseconds) fractional second timing.

- **Bits 19 – 16: SeqNum**

  This 4-bit sequence number is incremented modulo 16 for each successive Data Packet.

- **Bits 15-0: Packet Size**

  The Packet Size described in the first word of the Standard Signal Data Packet refers to the Size of VITA header (28 bytes / 7 words) summed with the Signal Data Payload size as calculated below:

Sample padding is not supported. Every packet must contain an integer number of I/Q pairs, each I/Q pair being “2 x sample depth” in bits. A whole number of such complex samples must fit into a whole number multiple of 32-bit units. For example,

- 5-bit samples = 10-bit complex samples; 16 samples fit into 5 units of 32 bits; so any multiple of 16 samples per packet is legal
  - 10 x 16 = 5 x 32 = 160 bits
- 6-bit samples = 12-bit complex samples; 8 samples fit into 3 units of 32 bits, so any multiple of 8 samples per packet is legal
  - 12 x 8 = 3 x 32 = 96 bits
- 7-bit samples = 14-bit complex samples; 16 samples fit into 7 units of 32 bits, so any multiple of 16 samples per packet is legal
  - 14 x 16 = 7 x 32 = 224 bits

Where 2 x <bits per sample> x <sample count granularity> = 32 x <32-bit unit granularity> and every value is a whole number. Table 8 shows all variations of bits per sample.

bits per sample	sample count granularity	32-bit unit granularity
4	4	1
5	16	5
6	8	3
7	16	7
8	2	1
9	16	9
10	8	5
11	16	11
12	4	3
13	16	13
14	8	7
15	16	15
16	1	1

Table 8. Sample Padding

- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream and/or Command Packet Stream, they will share Stream IDs. See Appendix 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.
- **Words 3 & 4: Class Identifier Field**
  - **Word 3, Bits 31-27: Pad Bit Count**

    The Pad Bit Count shall be an unsigned 5-bit integer indicating the number of non-data pad bits in the final word of the data payload. Permission to use bit padding in the final word of the Data Payload is dependent on the Information Class membership of the Packet Stream, see Table 10.

Information Class	Bit Padding Permitted
0x0000	No
0x0003	Yes

Table 9. Bit Padding Permission Information Classes using Packet Class 0x0000.

    - **Word 3, Bits 26-24: Reserved Bits**

      The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.

    - **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

      DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value (0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E.

    - **Word 4, Bits 31 – 16: Information Class Code**

      This Packet Class was originally generated for use with Information Class 0x0000 but may also be used with subsequently defined Information Classes that require a Real Time (picoseconds) based Data Packet, e.g., Information Class 0x0003.

    - **Word 4, Bits 15 – 0: Packet Class Code**

      The Packet Class Code for this Packet is 0x0000.

- **Word 5: Integer-seconds Timestamp**

  The value shall indicate seconds since epoch for the selected time reference (UTC, GPS, or POSIX). Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Words 6 & 7: Fractional-seconds Timestamp**

  Words 6 & 7 form a 64-bit field, formatted as an unsigned integer. The value in this field reflects the number of picoseconds since the most recent incrementation or reset of the Integer-seconds Timestamp field. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field.

- **Words 8 through N+7: Data Payload**

  The data payload shall consist of pairs of signal data samples in complex IQ format. The samples shall be signed integers of a bit depth called out in the associated context packets.

4.1.2 Packet Class 0x0002, Sample Count Signal Data Packets

Signal Data Packet Class		
Class Name: "Sample Count Signal Data," Code 0x0002		
Packet Stream Purpose: "To convey digitized I and Q samples in either the transmit direction or the receive direction."		
Packet Header		
Parameter	**Selected Options**	**Comments**
Packet Type	Signal Data Packet with Stream ID	Conveys digitized I and Q samples
Packet Size	Variable, user selected	Seven words in prologue plus "N" 32-bit words in the data payload
Stream Identifier	Yes	Selected by user at run time
Class ID	Present	OUI is 0x6A621E Packet Class Code is 0x0002
Integer Timestamp	Present	Routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate. May be periodically re-synchronized to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded reset to external reference.
Fractional Seconds Timestamp	Sample Count	
Packet Payload		
Parameter	**Selected Options**	**Comments**
Packing Method	Link Efficient	Data items are packed into 32-bit words. See Figure B-44 of VITA-49.2 for an illustration.
Data Item Size	Variable, user selected	Individual I and Q sample components may be 4 to 16 bits in length (I and Q pairs 8 to 32 bits in length)
Item Packing Field Size	Variable, twice the Data Item Size	
Real/Complex Type	Complex Cartesian	
Data Item Format	Signed Integer (V49.2 Signed Fixed-Point with code 00000, implying no fractional component)	
Sample-repeating/Channel-repeating	N/A	No repeating of any kind
Repeat Count	0	
Packet Trailer		
(Not Used)		

Table 10. Packet Class 0x0002, Sample Count Signal Data

This data packet is used for the Sample Count Signal Data packet and is the same for Receive or Transmit. The packet format is shown in Table 12.

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	Word #
0	0	0	1	1	0	0	0	TSI		0	1	Seq Num				Packet Size = N+7 words																1
Stream Identifier (assigned at run time)																																2
pad bit count					0	0	0	24-Bit DIFI CID (0x6A621E)																								3
Information Class = 0x0002																Packet Class = 0x0002																4
Integer Seconds Timestamp (per TSI field)																																5
Fractional Seconds Timestamp (Sample Count)																																6
																																7
Signal Data Payload (Complex Cartesian, 4 - 16-bit signed integers, N 32-bit words link-efficient packing, bit padding permitted at the end of the final word in payload)																																8
																																N+6
																																N+7

Table 11. Packet Class 0x0002 Format, Sample Count Signal Data

- **Word 1: Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x1 which indicates a Data packet with a stream ID.
  - **Bit 27: Class ID Indicator**

    This bit must be set to 1, which indicates the optional Class Identifier field is included.
  - **Bit 26: Trailer Indicator**

    This bit must be set to 0, which indicates no packet trailer is used.
  - **Bit 25: VITA49.0 Indicator**

    This bit must be set to 0 which indicates the Data Packet should not be interpreted as the prior VITA49.0 standard.
  - **Bit 24: VITA 49.2 Spectrum / Time**
  - This must be set to 0x0 which indicates the packet contains time data (rather than spectrum data which is not currently supported by this standard). This maintains compliance with VITA 49.2 specification [2] Rule 6.3.1-2.
  - **Bits 23-22: Timestamp Integer**

    The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 7.

  - **Bits 21-20: Timestamp Fractional**

    Bits 21-20 are set to 0x1 to indicate that this packet uses Sample Count fractional second timing.

  - **Bits 19 – 16: SeqNum**

    This 4-bit sequence number is incremented modulo 16 for each successive Data Packet.

  - **Bits 15-0: Packet Size**

    The Packet Size described in the first word of the Standard Signal Data Packet refers to the Size of VITA header (28 bytes / 7 words) summed with the Signal Data Payload size as calculated below:

- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream or Command Packet Stream, they will share Stream IDs. See Appendix 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.

- **Words 3 & 4: Class Identifier Field**
  - **Word 3, Bits 31-27: Pad Bit Count**

    The Pad Bit Count shall be an unsigned 5-bit integer indicating the number of non-data pad bits (from zero to 31) in the final word of the data payload.

  - **Word 3, Bits 26-24: Reserved Bits**

    The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.

  - **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value (0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E.

  - **Word 4, Bits 31 – 16: Information Class Code**

    This Packet Class was originally generated for use with Information Class 0x0002 but may also be used with subsequently defined Information Classes that require a Sample Count based Data Packet

  - **Word 4, Bits 15 – 0: Packet Class Code**

    The Packet Class Code for this Packet is 0x0002.

- **Word 5: Integer-seconds Timestamp**

The Integer Seconds Timestamp field will be incremented each time the Fractional Timestamp field reaches the value of the Sample Rate (nominally once per second). The value shall indicate seconds since epoch for the selected time reference (UTC, GPS or POSIX). Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Words 6 & 7: Fractional-seconds Timestamp**

  Words 6 & 7 form a 64-bit field, formatted as an unsigned integer. The value in this field reflects the number of sample counts since the most recent incrementation or reset of the Integer-seconds Timestamp field. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field.

- **Words 8 through N+7: Data Payload**

  The data payload shall consist of pairs of signal data samples in complex IQ format. The samples shall be signed integers of a bit depth called out in the associated context packets.

4.2 CONTEXT PACKET CLASSES

Whilst V49.2 provides the facility for Command Packets, it is acknowledged that for backwards compatibility with extant equipment, standard flow signal context packets *may* be used as a pseudo control emitted by the signal data stream emitter.

The necessity of acting on standard flow signal context packets, in real time or otherwise, depends on the application and on the availability of out-of-band management beyond the scope of this standard.

Context Packets may also be used by a device with a DIFI compliant interface that is monitoring one or more DIFI VITA 49.2 streams flowing on a network.

The Standard presently supports three Context Packet Classes, 0x0001, 0x0003, and 0x0004. Certain conventions apply to all Context Packets unless explicitly stated otherwise:

- All frequency and sample rate fields shall be expressed in Hz, and shall use the 64-bit, two's-complement format shown in Figure 5. This field has an integer and a fractional part with the radix point to the right of bit 20 in the second 32-bit word. All DIFI packets describing frequency or sample rate shall be expressed as an integer number of Hz, with all bits to the right of radix point set to zero.
- Corresponding to the associated Data Packet Stream, the SID location for Context Packets shall be at the point of generation of digital samples in the receive direction and at the point of consumption of digital samples within the digital to analog converter in the transmit direction.

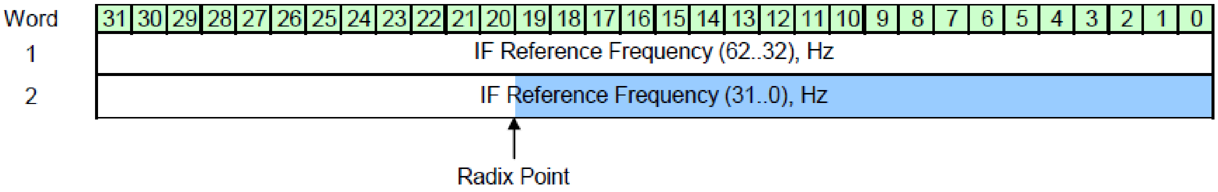


Figure 5. Format of Frequency and Rate fields within this Standard

4.2.1 Packet Class 0x0001, Standard Flow Signal Context Packets

Signal Context Packet Class		
Class Name: "Standard Flow Signal Context", Code 0x0001		
Packet Stream Purpose: "To convey Context related to the DIFI IQ Data Packet Stream with which it is paired by Stream ID"		
Packet Header		
Parameter	**Selected Options**	**Comments**
Packet Type	Context Packet with Stream ID	Conveys Context for paired Data Stream
Packet Size	27 words	
Stream Identifier	Yes	Matches SID for paired Data Stream
Class ID	Present	OUI is 0x6A621E Packet Class Code is 0x0001
Integer Timestamp	Present	May be UTC, POSIX, or GPS as specified in Packet Header
Fractional Seconds Timestamp	Real-time, picoseconds	May be locked to an external reference
Context Fields		
Parameter	**Selected Options**	**Comments**
Context Field Change Indicator	Present	
Reference Point Identifier	Present	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
Bandwidth	Present	Describes the equivalent analog bandwidth of the signal represented by the digital stream.
IF Reference Frequency	Present	In systems which employ an accessible analog IF signal, the IF Reference Frequency shall be populated with the sampling center frequency for IF conversion. In systems having an RF output or input and no accessible IF output or input, the IF Reference Frequency shall be populated with the value 0x00000000 at the source and ignored at the sink. The use of this field shall be determined by the “Reference Point” field.

RF Reference Frequency	Present	In systems which employ an analog IF, the RF Reference Frequency field shall be populated with the intended RF center frequency realized through analog conversion (IF to RF or RF to IF). In systems employing only direct RF conversion, the RF Reference Frequency field shall be populated with the sampling center frequency for direct RF conversion. The use of this field shall be determined by the “Reference Point” field.
IF Band Offset	Present	The IF Band Offset field describes the frequency offset of the center of the equivalent analog band occupied by the signal, either from the IF Reference Frequency in the case of an IF interface conversion device or the RF Reference Frequency in the case of an RF interface device.
Scaling Level	Present	The value in the field represents the value in dBFS of a sine wave having the same average power as the signal represented by the samples in the data payload.
Reference Level	Present	Describes the analog level in dBm at the Reference Point corresponding to a full scale sinusoid in the digital stream.
Gain	Present	One 32-bit word made up of two 16-bit fields, Gain 1 and Gain 2. These fields are reserved, populated with the value 0x0000 at the source and ignored at the sink. Usage per previous revisions of this standard is allowed, but it may be more useful to make use of the Reference Level in many situations, and interoperability is the responsibility of the vendor. Formatted per VITA 49.2 §9.5.3
Over Range Count	Not present	
Sample Rate	Present	The digital sample rate in Hz
Timestamp Adjustment	Present	Adjustments to the timestamp to account for implementation delays.
Timestamp Calibration	Present	Most recent time when timestamp was known to be correct (synchronized to external source)
State and Event Indicators	Present	Used to convey state of the calibrated time and frequency reference lock; refer to VITA 49.2 §9.10.8
Data Packet Payload Format	Present	Complex Cartesian (I and Q) samples only, link-efficient packing, signed fixed-point, no event or channel tags, I and Q sample sizes from 4 through 16 bits (same size for both), no sample component repeats. Bit padding is permitted or prohibited based on the Information Class in which this Packet Class is used.
Temperature	Not present	
Device ID	Not present	
Data Item Format	Signed fixed point	
Packet Trailer		
(Not Used)		

Table 12. Packet Class 0x0001, Standard Flow Signal Context

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>Word #</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>TSM</td><td colspan="2">TSI</td><td>1</td><td>0</td><td colspan="4">Seq Num</td><td colspan="16">Packet Size = 27 words</td><td>1</td></tr>
<tr><td colspan="32">Stream Identifier (assigned at run time)</td><td>2</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td colspan="24">24-Bit DIFI CID (0x6A621E)</td><td>3</td></tr>
<tr><td colspan="16">Information Class (number of incorporating class)</td><td colspan="16">Packet Class = 0x0001</td><td>4</td></tr>
<tr><td colspan="32">Integer Seconds Timestamp (per TSI field)</td><td>5</td></tr>
<tr><td colspan="32" rowspan="2">Fractional Seconds Timestamp (Real Time [picoseconds])</td><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="32">Context Indicator Field (0xFBB98000 -> context change or 0x7BB98000 -> no change)</td><td>8</td></tr>
<tr><td colspan="32">Reference Point = 0x00000064</td><td>9</td></tr>
<tr><td colspan="32" rowspan="2">Bandwidth</td><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td colspan="32" rowspan="2">IF Reference Frequency</td><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td colspan="32" rowspan="2">RF Reference Frequency</td><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td colspan="32" rowspan="2">IF Band Offset</td><td>16</td></tr>
<tr><td>17</td></tr>
<tr><td colspan="16">Scaling</td><td colspan="16">Reference Level</td><td>18</td></tr>
<tr><td colspan="16">Gain 1</td><td colspan="16">Gain 2</td><td>19</td></tr>
<tr><td colspan="32" rowspan="2">Sample Rate</td><td>20</td></tr>
<tr><td>21</td></tr>
<tr><td colspan="32" rowspan="2">Timestamp Adjustment</td><td>22</td></tr>
<tr><td>23</td></tr>
<tr><td colspan="32">Timestamp Calibration Time</td><td>24</td></tr>
<tr><td colspan="32">State and Event Indicators</td><td>25</td></tr>
<tr><td colspan="32" rowspan="2">Data Packet Payload Format</td><td>26</td></tr>
<tr><td>27</td></tr>
</table>

Table 13. Packet Class 0x0001 Format, Standard Flow Signal Context

- **Word 1: Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x4 which indicates a Context packet with a stream ID.
  - **Bit 27: Class Identifier Indicator**

    This must be set to 0x1 which indicates the optional Class Identifier field is included. See section 5.1.3 of the VITA 49.2 specification [2] for] for more information.
  - **Bits 26 – 25: Reserved**

    These reserved bits must be set to 0x0.
  - **Bit 24: Timestamp Mode**

    This bit sets the Timestamp Mode (TSM) to either coarse or fine timing, 0 for fine or precise timing, 1 for coarse or general timing. See VITA 49.2 Section 7.1.3 for more details of coarse and fine timing. The selection of fine versus coarse timing is determined by the Information Class in which this Context Packet Class, 0x0001, is used, shown in Table 15.

Information Class	Timestamp Mode
0x0000	Coarse (TSM = 1)
0x0003	Fine (TSM = 0)

Table 14. Timestamp Mode (TSM) field values for coarse and fine timing.

  - **Bits 23 – 22: Timestamp Integer Seconds**

    The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 7.
  - **Bits 21 – 20: Timestamp Fractional Seconds**

    The TSF field indicates the type of fractional seconds, which is Real Time (picoseconds) (0x2), for this Packet Class.
  - **Bits 19 – 16: SeqNum**

    This 4-bit sequence number is incremented modulo 16 for each successive Context packet.
  - **Bits 15 – 0: Packet Size (Header, Bits 15 - 0)**

    The number of 32-bit words in the packet including the header and any optional fields. Fixed at 27 words for this Standard Flow Signal Context Packet Class.
- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream or Command Packet Stream, they will share Stream IDs. See Appendix 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.
- **Words 3 & 4: Class Identifier**
  - **Bits 31-27: Pad Bit Count**

    The Pad Count Bits are set to zero in this Context Packet, which has no Data Payload.
  - **Bits 26-24: Reserved Bits**

    The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.
  - **Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value

(0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E.

  - **Bits 31 – 16: Information Class Code**

    This Packet Class was originally generated as part of Information Class 0x0000 but may also be used with subsequently defined Information Classes that require a Real Time (picoseconds) based Context Packet, e.g., Information Class 0x0003.

  - **Bits 15 – 0: Packet Class Code**

    The Packet Class Code is 0x0001.

- **Word 5: Integer-seconds Timestamp**

  The seconds since epoch for the selected time reference (UTC, GPS or POSIX). Note that only UTC time will include leap seconds. The field is formatted as unsigned integer. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Words 6 & 7: Fractional-seconds Timestamp**

  The number of picoseconds past the integer seconds. The field is formatted as unsigned integer. The field is reset to zero when the Integer Seconds Timestamp field is incremented or reset. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Word 8: Context Indicator Field (CIF 0)**

  This field indicates which of the optional CIF 0 metadata fields are included and if a value has changed since the last transmitted context packet. 0 shows the required context fields. See Section 9 of the VITA 49.2 specification [2] for additional information.

  <Recommend a diagram of CIF0, with each bit explained, be placed here.

Context Field Change Indicator	Reference Point Identifier	Bandwidth	IF Reference Frequency	RF Reference Frequency	RF Reference Frequency Offset	IF Band Offset	Reference Level	Gain	Over-range Count	Sample Rate	Timestamp Adjustment	Timestamp Calibration Time	Temperature	Device Identifier	State/Event Indicators	Signal Data Packet Payload Format	Formatted GPS	Formatted INS	ECEF Ephemeris	Relative Ephemeris	Ephemeris Ref ID	GPS ASCII	Context Association Lists	Field Attributes Enable	Reserved for CIF Expansion	Reserved for CIF Expansion	Reserved for CIF Expansion	CIF 3 Enable	CIF 2 Enable	CIF 1 Enable	Reserved
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

Figure 6. Context/Command Indicator Field (CIF) 0 Bit Assignment

- **Words 10 & 11: Bandwidth**

  The useable bandwidth of the digitized signal. The bandwidths for the standard are specified in 1 Hz increments. Refer to section 9.5.1 of the VITA 49.2 specification [2] for complete details.

- **Words 12 & 13: IF Reference Frequency**

  In systems which employ an accessible analog IF signal, the IF Reference Frequency shall be populated with the sampling center frequency for IF conversion. In systems having an RF output or input and no accessible IF output or input, the IF Reference Frequency shall be populated with the value 0x00000000 at the source and ignored at the sink. The use of this field shall be determined by the value in the “Reference Point” field.

- **Words 14 & 15: RF Reference Frequency**

  In systems which employ an analog IF, the RF Reference Frequency field shall be populated with the intended RF center frequency realized through analog conversion (IF to RF or RF to IF). In systems employing only direct RF conversion, the RF Reference Frequency field shall be populated with the sampling center frequency for direct RF conversion. The use of this field shall be determined by the value in the “Reference Point” field.

- **Words 16 & 17: IF Band Offset**

  The stream offset from the IF center frequency of the digitized signal which defaults to 0 Hz. The IF center frequency is always 0 Hz for zero IF architectures. The stream offset is a signed number with a 1 Hz resolution and can be set anywhere within the system bandwidth as long as no portion of the stream bandwidth extends beyond the system bandwidth edges. The system bandwidth is defined by the bandwidth parameter above.

  The IF Band Offset value is the Stream Offset for the receive direction. It is used as the default Stream Offset in the transmit direction. Refer to section 9.5.4 of the VITA 49.2 specification [2] for complete details.

- **Word 18: Reference Level**

  The purpose of the Reference Level field is to relate the physical signal amplitude at the reference point with the data samples in the Signal Data packet. Refer to section 9.5.9 of the VITA 49.2 specification [2] for complete details. Refer to VITA 49.2 specification [2] section B.6 for an example.

  - **Bits 31 – 16: Scaling Level**

    This field is used to describe scaling applied to the digital signal representation to prevent overflow of the signal sample words (4-16 bits) in the Signal Data packet payload. Filling the Scaling Level field is optional. Note, it is used in the transmit direction only, and the value placed in the field shall default to a value of 0x0000 when the field is not used.

    When used, the field characterizes the digital scaling of the samples in the IP payload. The value in the field represents the value in dBFS (dB full-scale) of a sine wave having the same average power as the signal represented by the samples in the data payload.

  - **Bits 15 – 0: Reference Level**

    This field is used to relate the physical analog signal amplitude at the reference point with the data samples in the associated Signal Data packet. Filling the Reference Level field is mandatory.

    In the receive direction, the field describes a power level in dBm incident at the Reference Point. The power value conveyed by the Reference Level field is the AC power of a single sine wave at the Reference Point that results in a full-scale digitized sine wave in the payload of the paired Data Packet Stream.

In the transmit direction, the field specifies the power level in dBm that is intended at the Reference Point in response to a full-scale digital representation of a sine wave in the Data Payload.

- **Word 19: Gain/Attenuation**

  One 32-bit word made up of two 16-bit fields, Gain 1 and Gain 2. These fields are reserved, populated with the value 0x0000 at the source and ignored at the sink. Usage per previous revisions of this standard is allowed, but it may be more useful to make use of the Reference Level in many situations, and interoperability is the responsibility of the vendor. Refer to section 9.5.3 of the VITA 49.2 specification [2] for complete details. Refer to VITA 49.2 section B.7 for an example.

- **Words 20 & 21: Sample Rate**

  The sampling rate of the samples in the Signal Data packets which can be set. Refer to section 9.5.12 of the VITA 49.2 specification [2] for complete details.

  For interoperability purposes DIFI refers the reader to the external Sample Rate Vendor Interoperability area of the DIFI website.

- **Words 22 & 23: Timestamp Adjustment**

  Adjustments to the timestamp to account for implementation delays. This 64-bit field is formatted as signed integer and represents the signal delay from SID location to the Reference Point. This defaults to 0 femtoseconds. See Appendix 5.2 for clarification and refer to Section 9.7.3.1 of the VITA 49.2 specification [2] for complete details.

- **Word 24: Timestamp Calibration Time**

  Indicates the last time the Integer Seconds Timestamp was known to be correct. Refer to Section 9.7.3.3 of the VITA 49.2 specification [2] for complete details.

- **Word 25: State and Event Indicators**

  Used to convey the state of the calibrated time (bit 19) and frequency reference lock (bit 17) for the samples in the Signal Data packets.

  The calibrated time reference can be IRIG-B, IRIG-DC, 1PPS, NTP, GPS.

  The frequency reference can be 10 MHz, IRIG-B, IRIG-DC or 1PPS, GPS.

  Refer to section 9.10.8 of the VITA 49.2 specification [2] for complete details.

- **Words 26 & 27: Data Packet Payload Format**

  This field is required to interpret the samples in the Signal Data packets. This standard support only supports complex Cartesian samples (I and Q), link-efficient packing, signed integer (V49.2 signed fixed point with code 00000) and no event or channel tags. It supports sample sizes from 4 through 16 bits without sample component repeats. Refer to section 9.13.3 of the VITA 49.2 specification [2] for complete details.

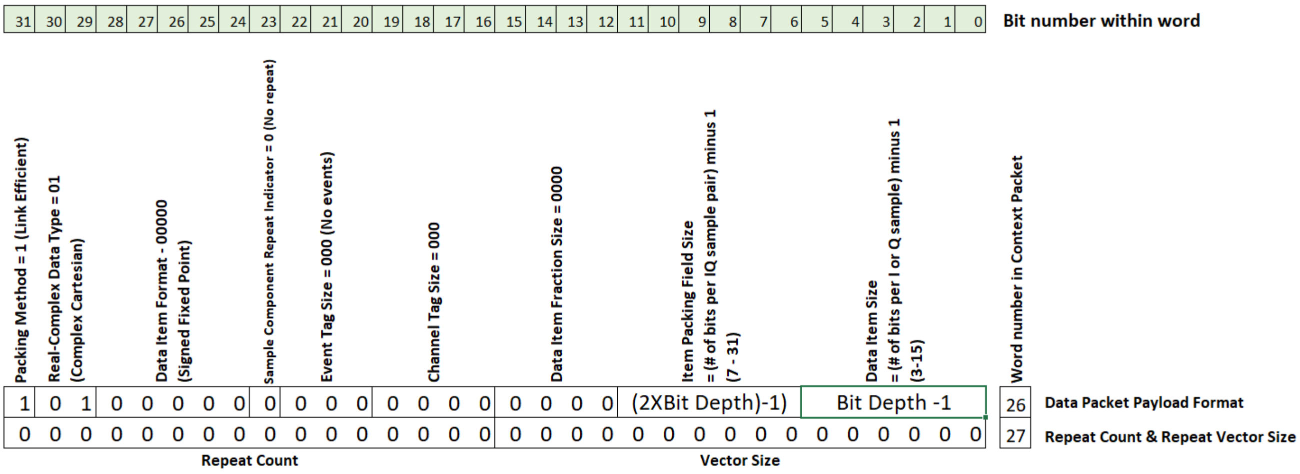


Figure 7. Data Packet Payload Format sub-field definitions and values

The packet rate for this Standard Flow Signal Context Packet may be set from 0 (off) through 20 packets/second for any configuration of stream sample rate, sample size, and data packet size for the standard context flows.

Additionally, Standard Flow Signal Context Packet transmission is required upon change to any signal context packet field, e.g., change to the “Reference Amplitude” field.

4.2.2 Packet Class 0x0003, Sample Count Signal Context Packet

Signal Context Packet Class		
Class Name: "Sample Count Signal Context" Code 0x0003		
Packet Stream Purpose: "To convey Context related to the IQ Data Packet Stream with which it is paired by Stream ID"		
Packet Header		
Parameter	**Selected Options**	**Comments**
Packet Type	Context Packet with Stream ID	Conveys Context for paired Data Stream
Packet Size	27 words	
Stream Identifier	Yes	Matches SID for paired Data Stream
Class ID	Present	OUI is 0x6A621E Packet Class Code is 0x0003
Integer Timestamp	Present	Routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate. May be periodically re-synchronized to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded reset to external reference.
Fractional Seconds Timestamp	Sample Count	
Context Fields		
Parameter	**Selected Options**	**Comments**
Context Field Change Indicator	Present	
Reference Point Identifier	Present	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
Bandwidth	Present	
IF Reference Frequency	Present	In systems which employ an analog IF, the IF Reference Frequency shall be populated with the sampling center frequency for IF conversion. In systems employing devices having a digital stream input and an RF output, the IF Reference Frequency shall be populated with the value 0x00000000 at the source and ignored at the sink. The use of this field shall be determined by the “Reference Point” field.
RF Reference Frequency	Present	In systems which employ an analog IF, the RF Reference Frequency field shall be populated with the intended RF center frequency realized through analog conversion (IF to

		RF or RF to IF) if known to the Data Stream source, and otherwise populated with zeros. In systems employing only direct RF conversion, the RF Reference Frequency field shall be populated with the sampling center frequency for direct RF conversion. The use of this field shall be determined by the “Reference Point” field.
IF Band Offset	Present	The IF Band Offset field describes the frequency offset of the center of the equivalent analog band occupied by the signal, either from the IF Reference Frequency in the case of an IF interface conversion device or the RF Reference Frequency in the case of an RF interface device.
Scaling Level	Present	The value in the field represents the value in dBFS of a sine wave having the same average power as the signal represented by the samples in the data payload.
Reference Level	Present	Describes the analog level in dBm at the Reference Point corresponding to a full-scale sinusoid in the digital stream.
Gain	Present	One 32-bit word is made up of two 16-bit fields, Gain 1 and Gain 2. These fields are reserved, populated with the value 0x0000 at the source and ignored at the sink. Usage per previous revisions of this standard is allowed, but it may be more useful to make use of the Reference Level in many situations, and interoperability is the responsibility of the vendor. Formatted per VITA 49.2 §9.5.3
Over Range Count	Not present	
Sample Rate	Present	The digital sample rate in Hz
Timestamp Adjustment	Present	64-bit field indicating the signal delay in femtoseconds between the Reference Point called out in this packet and the SID Location.
Timestamp Calibration	Present	Most recent time when timestamp was known to be correct (synchronized to external source)
State and Event Indicators	Present	Used to convey state of the calibrated time and frequency reference lock; refer to VITA 49.2 §9.10.8
Data Packet Payload Format	Present	Complex Cartesian (I and Q) samples only, link-efficient packing with zero-padding permitted in the final word of the Data Payload, signed fixed-point, no event or channel tags, I and Q sample sizes from 4 through 16 bits (same size for both), no sample component repeats.
Temperature	Not present	
Device ID	Not present	
Data Item Format	Signed fixed point	
Packet Trailer		
(Not Used)		

Table 15. Packet Class 0x0003, Sample Count Signal Context

This context packet shall be used for the Sample Count Signal Context packet and is the same for Receive or Transmit. The packet format is shown in Table 17. The VITA 49.2 specification [2] has renamed the original IF Context packet to Signal Context Indicator Field 0 (CIF 0).

<table>
<tr><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Word #</th></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td colspan="2">T S I</td><td>0</td><td>1</td><td colspan="4">Seq Num</td><td colspan="16">Packet Size = 27 words</td><td>1</td></tr>
<tr><td colspan="32">Stream Identifier (assigned at run time)</td><td>2</td></tr>
<tr><td colspan="5">0 0 0 0 0</td><td>0</td><td>0</td><td>0</td><td colspan="24">24-Bit DIFI CID (0x6A621E)</td><td>3</td></tr>
<tr><td colspan="16">Information Class (number of incorporating class)</td><td colspan="16">Packet Class = 0x0003</td><td>4</td></tr>
<tr><td colspan="32">Integer Seconds Timestamp (per TSI)</td><td>5</td></tr>
<tr><td colspan="32" rowspan="2">Fractional Seconds Timestamp (Sample Count)</td><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="32">Context Indicator Field (0xFBB98000 -> context change or 0x7BB98000 -> no change)</td><td>8</td></tr>
<tr><td colspan="32">Reference Point = 0x00000064</td><td>9</td></tr>
<tr><td colspan="32" rowspan="2">Bandwidth</td><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td colspan="32" rowspan="2">IF Reference Frequency</td><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td colspan="32" rowspan="2">RF Reference Frequency</td><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td colspan="32" rowspan="2">IF Band Offset</td><td>16</td></tr>
<tr><td>17</td></tr>
<tr><td colspan="16">Scaling</td><td colspan="16">Reference Level</td><td>18</td></tr>
<tr><td colspan="16">Gain 1</td><td colspan="16">Gain 2</td><td>19</td></tr>
<tr><td colspan="32" rowspan="2">Sample Rate</td><td>20</td></tr>
<tr><td>21</td></tr>
<tr><td colspan="32" rowspan="2">Timestamp Adjustment</td><td>22</td></tr>
<tr><td>23</td></tr>
<tr><td colspan="32">Timestamp Calibration Time</td><td>24</td></tr>
<tr><td colspan="32">State and Event Indicators</td><td>25</td></tr>
<tr><td colspan="32" rowspan="2">Data Packet Payload Format</td><td>26</td></tr>
<tr><td>27</td></tr>
</table>

Table 16. Packet Class 0x0003 Format, Sample Count Signal Context

- **Word 1: Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x4 which indicates a Context packet with a stream ID.
  - **Bit 27: Class Identifier**

    This bit must be set to 1, which indicates the optional Class Identifier field is included. See section 5.1.3 of the VITA 49.2 specification [2] for] for more information.
  - **Bits 26 – 25: Reserved**

    These reserved bits shall be set to 0x0.
  - **Bit 24: Timestamp Mode**

    The TSM bit is set to 0 indicating the timestamp is conveying precise timing for packets with the associated Stream ID.
  - **Bits 23 – 22: Timestamp Integer**

    The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 7.

  - **Bits 21 – 20: Timestamp Fractional**

    The TSF field indicates the type of fractional seconds is Sample Count (0x1).

  - **Bits 19 – 16: SeqNum**

    This 4-bit sequence number is incremented modulo 16 for each IF Context packet.

  - **Bits 15 – 0: Packet Size**

    The number of 32-bit words in the packet including the header and any optional fields. Fixed at 27 words for the Sample Count Flow Signal Context packet.

- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream or Command Packet Stream, they will share Stream IDs. See Appendix 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.

- **Words 3 & 4: Class Identifier**

  - **Bits 31-27: Pad Bits Count**

    The Pad Bit Count is set to zero for this Context Packet that has no Data Payload.

  - **Reserved Bits (Bits 26-24)**

    The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.

  - **Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value (0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E.

  - **Bits 31 – 16: Information Class Code**

    This Packet Class was originally generated for use with Information Class 0x0002 but may also be used with subsequently defined Information Classes that require a Sample Count based Context Packet.

  - **Bits 15 – 0: Packet Class Code**

    The Packet Class Code for this Packet is 0x0003.

- **Word 5: Integer-seconds Timestamp**

  The Integer Seconds Timestamp field will nominally be incremented each time the Fractional Timestamp field reaches the value of the Sample Rate (nominally once per second). The seconds since epoch for the selected time reference (UTC, GPS or POSIX).

Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Words 6 & 7: Fractional-seconds Timestamp**

  The value in this field reflects the number of sample counts since the most recent incrementation or reset of the Integer-seconds Timestamp field. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field.

- **Word 8: Context Indicator Field (CIF 0)**

  This field indicates which of the optional CIF 0 metadata fields are included and if a value has changed since the last transmitted context packet. Table 16 shows the context fields that will be included. See Section 9 of the VITA 49.2 specification [2] for additional information.

- **Word 9: Reference Point**

  The Reference Point is the point in the signal path that the Sample Count Flow Signal Context Packet is conveying timing information about. See Appendix 5.2 for more details.

- **Word 10 & 11: Bandwidth**

  The useable bandwidth of the digitized signal. The bandwidths for the standard are specified in 1 Hz increments. Refer to section 9.5.1 of the VITA 49.2 specification [2] for complete details.

- **Words 12 & 13: IF Reference Frequency**

  The IF center frequency of the digitized signal which defaults to 0 due for zero IF architectures. Refer to section 9.5.5 of the VITA 49.2 specification [2] for complete details.

- **Words 14 & 15: RF Reference Frequency**

  The center frequency of the RF spectrum on the RF input port for the RF-to-IP direction or the center of the spectrum on the RF output port for the Transmit direction. The RF reference frequency in the Transmit direction is status information only. The output center frequency is programmed and is independent of the RF frequency at the stream source to allow frequency translation. Refer to section 9.5.10 of the VITA 49.2 specification [2] for complete details.

- **Words 16 & 17: IF Band Offset**

  The stream offset from the IF center frequency of the digitized signal which defaults to 0 Hz. The IF center frequency is always 0 Hz for zero IF architectures. The stream offset is a signed number with a 1 Hz resolution and can be set anywhere within the system bandwidth as long as no portion of the stream bandwidth extends beyond the system bandwidth edges. The system bandwidth is defined by the bandwidth parameter above.

  The IF Band Offset value is the Stream Offset for the RF-to-IP direction. It is used as the default Stream Offset in the Transmit direction but can be overridden. Refer to section 9.5.4 of the VITA 49.2 specification [2] for complete details.

- **Word 18: Reference Level**

  The purpose of the Reference Level field is to relate the physical signal amplitude at the reference point with the data samples in the Signal Data packet. Refer to section 9.5.9 of the VITA 49.2 specification [2] for complete details. Refer to VITA 49.2 specification [2] section B.6 for an example.

  - **Bits 31 – 16: Scaling Level**

    This field is used to describe scaling applied to the digital signal representation to prevent overflow of the signal sample words (4-16 bits) in the Signal Data packet payload. Filling the Scaling Level field is optional. Note, it is used in the transmit direction only, and the value placed in the field shall default to a value of 0x0000 when the field is not used.

    When used, the field characterizes the digital scaling of the samples in the IP payload. The value in the field represents the value in dBFS (dB full-scale) of a sine wave having the same average power as the signal represented by the samples in the data payload.

  - **Bits 15 – 0: Reference Level**

    This field is used to relate the physical analog signal amplitude at the reference point with the data samples in the associated Signal Data packet. Filling the Reference Level field is mandatory.

    In the receive direction, the field describes a power level in dBm incident at the Reference Point. The power value conveyed by the Reference Level field is the AC power of a single sine wave at the Reference Point that results in a full-scale digitized sine wave in the payload of the paired Data Packet Stream.

    In the transmit direction, the field specifies the power level in dBm that is intended at the Reference Point in response to a full-scale digital representation of a sine wave in the Data Payload.

- **Word 19: Gain/Attenuation**

  One 32-bit word made up of two 16-bit fields, Gain 1 and Gain 2. These fields are reserved, populated with the value 0x0000 at the source and ignored at the sink. Usage per previous revisions of this standard is allowed, but it may be more useful to make use of the Reference Level in many situations, and interoperability is the responsibility of the vendor. Refer to section 9.5.3 of the VITA 49.2 specification [2] for complete details. Refer to VITA 49.2 section B.7 for an example.

- **Words 20 & 21: Sample Rate**

  The sampling rate of the samples in the Signal Data packets which can be set. Refer to section 9.5.12 of the VITA 49.2 specification [2] for complete details.

  For interoperability purposes DIFI refers the reader to the external Sample Rate Vendor Interoperability area of the DIFI website.

- **Words 22 & 23: Timestamp Adjustment**

With the presence of Prologue Timestamp and the inclusion of the Reference Point field and this Timestamp Adjustment field in this Context Packet, the value in the Timestamp adjustment field should be a 64-bit two's-complement value in femtoseconds, representing the signal delay between the Reference Point called out in this Context Packet and the SID location. On the transmit path, this value will generally be positive, and on the receive path, it will generally be negative. Appendix 5.2 describes the relationship between the signal timing, SID and Reference Point locations, and the Timestamp Adjustment.

- **Word 24: Timestamp Calibration Time**

  Indicates the last time the timestamp was known to be correct. This is populated on the RF-to-IP side for applications that require knowledge of when the timing signal was last locked. Refer to Section 9.7.3.3 of the VITA 49.2 specification [2] for complete details.

- **Word 25: State and Event Indicators**

  Used to convey the state of the calibrated time (bit 19) and frequency reference lock (bit 17) for the samples in the Signal Data packets.

  The calibrated time reference can be IRIG-B, IRIG-DC, 1PPS, NTP, GPS.

  The frequency reference can be 10 MHz, IRIG-B, IRIG-DC or 1PPS, GPS.

  The lock statuses of the time and frequency references are updated about once per second in the RF-to-IP direction.

  The status information is used by the Transmit side to determine if it can operate in Programmed Delay mode and if it can measure end-to-end latency (Measured Delay) or Network Delay. The Measured and Network Delays will be set to 0 if the calibrated time (bit 19) is not locked on the RF-to-IP side.

  Refer to section 9.10.8 of the VITA 49.2 specification [2] for complete details.

- **Words 26 & 27: Data Packet Payload Format**

  This field is required to interpret the samples in the Signal Data packets. This standard support only supports complex Cartesian samples (I and Q), link-efficient packing, signed integer (V49.2 signed fixed point with code 00000) and no event or channel tags. It supports sample sizes from 4 through 16 bits without sample component repeats. Refer to section 9.13.3 of the VITA 49.2 specification [2] for complete details.

  All sub-field values in the Data Packet Payload field are specified by this standard except for those that define the bit depth of the samples (Word 26, bits 11-6 and bits 5-0), which the user shall determine based on application requirements. The meanings and specified values of the sub-fields are illustrated in **Figure 7.**

4.2.3 Packet Class 0x0004, Version Flow Signal Context Packet

This context packet is used to convey type and version information and conveys precise time of day for software applications.

The version packet format is created on the receive side and used by the transmit side to auto-select a compatible packet format, if possible. The version packet may optionally be used on the transmit flow when appropriate for the application.

The Packet Format is shown in Table 18 and is new in VITA 49.2 specification [2], which has added four new Context Indicator Fields to provide for additional metadata for the Signal Data Packets. The Version information is contained in the CIF 1 indicator field (see Section 9.1 in the VITA 49.2 specification [2]). See Section 4.1.1 for an explanation of TSI, Sequence Number, Packet Size, and Stream ID plus the Integer and Fractional Timestamps.

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td colspan="2">TSI</td><td>1</td><td>0</td><td colspan="4">SeqNum</td><td colspan="16">Packet Size = 11 words</td></tr>
<tr><td colspan="32">Stream ID = variable</td></tr>
<tr><td colspan="8">0 0 0 0 0 0 0 0</td><td colspan="24">OUI = 0x6A621E</td></tr>
<tr><td colspan="16">Information Class Code = 0x0001</td><td colspan="16">Packet Class Code = 0x0004</td></tr>
<tr><td colspan="32">Integer-seconds Timestamp (UTC/GPS/POSIX seconds)</td></tr>
<tr><td colspan="32">Fractional-seconds Timestamp (picoseconds)</td></tr>
<tr><td colspan="32">Context Indicator Field 0 (0x80000002 -> context change or 0x00000002 -> no change)</td></tr>
<tr><td colspan="32">Context Indicator Field 1 = 0x0000000C</td></tr>
<tr><td colspan="32">V49 Spec Version = 0x00000004</td></tr>
<tr><td colspan="7">Year</td><td colspan="9">Day</td><td colspan="6">Revision</td><td colspan="4">Type</td><td colspan="6">ICD Version</td></tr>
</table>

Table 17. Version Flow Signal Context Packets

- **Words 3&4: Class Identifier**
  - **Word 3, Bits 31-27: Padding Bits**

    The Padding Bits are set to zero indicating that padding is not permitted.
  - **Bits 27-24: Reserved Bits**

    The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.
  - **Bits 23 – 0: Organizationally Unique Identifier**

    DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. This ID Value (0x6A621E) MUST be inserted in the OUI field of the Class Identifier. The canonical form of this CID is 6A-62-1E.
  - **Word 4, Bits 31 – 16: Information Class Code**

    The Information Class must be 0x0001 and cannot be changed when sending version information. The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

  - **Packet Class Codes (Bits 15 – 0)**

    The Packet Class must be 0x0004 when sending version information. The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

- **Word 8: Context Indicator Field 0 (CIF 0)**

  This field indicates which of the optional CIF 0 metadata fields are included and if a value has changed since the last transmitted context packet. Table 17 shows that the CIF 1 word is included. No other CIF 0 fields are allowed. See Section 9 of the VITA 49.2 specification [2] for additional information.

- **Word 9: Context Indicator Field 1 (CIF 1)**

  This field shows that the only two CIF 1 parameters included are the V49 Spec Version and the Version field. No other CIF 1 fields are allowed. See Section 9 of the VITA 49.2 specification [2] for additional information.

- **Words 10 & 11: V49 Spec Version**

  The V49 version must be 0x4 (VITA 49.2 specification [2]). The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

  - **Year (Bits 31 – 25)**

    The year the software/firmware was compiled starting from the year 2000. See section 9.10.4 of the VITA 49.2 specification [2] for additional details.

  - **Day (Bits 24 - 16)**

    The day within the year the software/firmware was compiled starting with a 1 for January 1st. See section 9.10.4 of the VITA 49.2 specification [2] for additional details.

  - **Revision (Bits 15 – 10)**

    The Revision number can be used to account for which version created on the same year and day is being used. This will normally be set to 1. See Section 9.10.4 of the VITA 49.2 specification [2] for additional details.

  - **Type (Bits 9 – 6)**

    The user defined subfield within the version word is used to convey the type of device. The types which may be assigned are 0..15. This field shall be set to 0x0. The types are currently undefined.

  - **ICD Version (Bits 5 – 0)**

    This subfield denotes the version of the data plane standard, as shown in Table 18.

Version Code	Meaning
0	Version 1 corresponds to DIFI v1.x
1 - 31	Reserved

Table 18. The Meaning of the Version Codes

4.3 COMMAND PACKET CLASSES

VITA 49.2 specifies the Command Packet type. There are two sub-types within this packet type, Control Packets and Acknowledge Packets. At the present revision, this DIFI Standard uses only Control Packets. Where descriptions apply to all Command Packet types, the “Command Packet” nomenclature is used. When features described apply only to Control Packets or the comment refers to a specific Control Packet, the “Control Packet” nomenclature is used.

4.3.1 Packet Class 0x0005, Sample Count Timing Flow Control

This Control Packet is used for the standard data flow. The packet documentation is shown in Table 20. See Section 4.1.1 for an explanation of TSI, Sequence Number, Packet Size, Stream ID, OUI, Information Class, Packet Class, plus the Integer and Fractional Timestamps.

Timing Flow Control Packet Class		
Class Name: "Sample Count Timing Flow Control," Code 0x0005		
Packet Stream Purpose: "To provide timing and buffer level information to permit synchronization of upstream devices"		
Packet Header		
Parameter	**Selected Options**	**Comments**
Packet Type	Control Packet with Stream ID	Conveys timing and buffer fill and status information for paired Data Stream
Packet Size	21 words	
Stream Identifier	Yes	Matches SID for paired Data Stream
Class ID	Present	OUI is 0x6A621E Packet Class Code is 0x0005
Integer Timestamp	Present	Routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate. May be periodically re-synchronized to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded reset to external reference.
Fractional Seconds Timestamp	Sample Count	
Context Fields		
Parameter	**Selected Options**	**Comments**
CAM Field	Present	
Message ID	Present	Sequentially assigned to the series of Control Packets issued by a Controller device
Controllee ID	Present	Pre-assigned value identifying each Controllee device in a system

Controller ID	Present	Pre-assigned value identifying each Controller device in a system
Control Indicator Field CIF 0	Present	32-bit word indicating which fields are present in the Control Packet; in the case of this Flow Control Packet, indicates the presence of the Reference Point field, the Timestamp Adjustment field, and the CIF1 field
Control Indicator Field CIF 1	Present	32-bit field indicating which fields are present in the Control Packet; in the case of this Flow Control Packet, indicates the presence of the Buffer Size (3-word) Field
Reference Point Field		
Reference Point	Present	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
Sample Rate Field		
Sample Rate	Present	64-bit field indicating the digital sample rate in Hz. Unsigned integer with the radix point to the right of bit 20in the second 32-bit word of the 64-bit field. Only integer Hz sample rates are permitted, that is, all bits to the right of the radix point must be zero.
Timestamp Adjustment Field		
Timestamp Adjustment	Present	64-bit field indicating the signal delay in femtoseconds between the Reference Point called out in this packet and the SID Location called out in the associated Context Packet. This field is formatted as a signed integer
Buffer Size Fields		
Buffer Size	Present	64-bit field indicating the size of the Buffer in bytes. This field is formatted as an unsigned integer
Buffer Level/Buffer Status	Present	The 16 MSBs of this field are reserved. The next 8 MSBs comprise the Buffer Level sub-field. The four MSBs of the Buffer Status field are used to extend the Buffer Level sub-field to 12-bit resolution. The Buffer Level subfield represents an average of the buffer fill level where the details of the averaging are left to the implementation. The four LSBs of the Buffer Status sub-field provide discrete status indicators. In the description, immediately following, of the four status indicator bits, the term «current interval» shall refer to the interval between the issuance of the previous Flow Control

		Packet and the issuance of the present Flow Control Packet. • The Buffer Overflow (set to «1» whenever a buffer overflow occurs during the current interval). • The Nearly Full indicator (set to «1» if the Buffer Level exceeds the nearly full threshold during the current interval). • The Nearly Empty indicator (set to «1» if the Buffer Level falls below the nearly empty threshold during the current interval). • The Buffer Underflow (set to «1» if the Buffer underflows during the current interval).

Table 19. Packet Class 0x0005, Sample Count Timing Flow Control

The packet format is shown in Table 21.

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	Word #
0	1	1	0	1	0	0	0	TSI		0	1	Packet Count				Packet Size (21 Words)																1
Stream Identifier																																2
0	0	0	0	0	0	0	0	24-Bit DIFI CID (0x6A621E)																								3
Information Class (number of incorporating class)																Packet Class= 0x0005																4
Integer Seconds Timestamp (per TSI field)																																5
Fractional Seconds Timestamp (Sample Count)																																6
																																7
1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13
Reference Point (Default = 0x00000064)																																14
Sample Rate																																15
																																16
Timestamp Adjustment (femtoseconds)																																17
																																18
Buffer Size																																19
																																20
Reserved																Level												OF	NF	NE	UF	21

Table 20. Packet Class 0x0005 Format, Sample Count Timing Flow Control

- **Word 1: Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x6 which indicates a Command Packet with a stream ID.
  - **Bit 27: Class Identifier**

    This bit must be set to 1 which indicates the optional Class Identifier field is included. See section 5.1.3 of the VITA 49.2 specification [2] for] for more information.

    - **Bits 26 – 24: Control vs Acknowledge indicators**

      These bits must be set to 0x0 for a Command Packet (that is not a cancellation packet).

    - **Bits 23 – 22: Timestamp Integer**

      The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 7.

    - **Bits 21 – 20: Timestamp Fractional**

      The TSF field indicates the type of fractional seconds and is set for Sample Count (0x1).

    - **Bits 19 – 16: SeqNum**

      This 4-bit sequence number is incremented modulo 16 for each sequential Flow Control Packet.

    - **Bits 15 – 0: Packet Size**

      The number of 32-bit words in the packet including the header and any optional fields. Fixed at 18 words for the Timing Flow Control packet.

- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream or Command Packet Stream, they will share Stream IDs. See Appendix 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.

  The SID location must be documented, and in this Standard, the SID location shall be the digital interface of the IFC, that is the point of generation of samples out of the ADC in the receive path direction and the point of consumption of samples within the DAC in the transmit path direction. If in addition to an IFC the system includes devices with both digital input and digital output (e.g., a digital combiner or splitter), the SID(s) for streams feeding such devices in the transmit direction should be at the point at which the samples are consumed, at the downstream end of the digital link.

- **Words 3,4: Class Identifier**
    - **Bits 31 – 27: Padding Bits**

      The Pad Bit Count is set to zero.

    - **Bits 26 – 24: Reserved Bits**

      The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.

    - **Bits 23 – 0: Organizationally Unique Identifier (OUI)**

      DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value

(0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E.

  - **Bits 31 – 16: Information Class Code**

    This Packet Class was originally generated for use with Information Class 0x0002 but may also be used with subsequently defined Information Classes that require a Sample Count based Flow Control Packet.

  - **Bits 15 – 0: Packet Class Code**

    The Packet Class for this packet is 0x0005.

- **Word 5: Integer-seconds Timestamp**

  The Integer Seconds Timestamp field will nominally be incremented each time the Fractional Timestamp field reaches the value of the Sample Rate (nominally once per second). Upon issuance of an external reset signal, the Integer-seconds Timestamp shall be reset to the external source specified in the header. The seconds since epoch for the selected time reference (UTC, GPS or POSIX). Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Words 6,7: Fractional-seconds Timestamp**

  The value in this field reflects the number of sample count intervals since the incrementation or reset of the integer seconds. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Word 9: Message ID**

  Each Timing Flow Control Packet corresponding to any specific Stream ID shall be issued with a unique sequential 32-bit Message ID

- **Word 10: Controller ID**

  In systems having multiple controller devices, each shall be assigned a distinct 32-bit Controller ID. This value should default to 0x00000000 (see Recommendation 4.3.1-1).

  Recommendation 4.3.1-1

  In systems not requiring distinct Controller IDs (e.g., systems having a single controller device), a Controller ID of 0x00000000 should be used.

- **Word 11: Controllee ID**

  In systems having multiple controllee devices, each shall be assigned a distinct 32-bit Controller ID if there is a requirement that each be controlled separately. This value should default to 0x00000000 (see Recommendation 4.3.1-2).

  Recommendation 4.3.1-2

  In systems not requiring distinct Controllee IDs (e.g., systems having a single controllee device, or systems in which all controllee devices are to respond identically), a Controllee ID of 0x00000000 should be used.

- **Word 12: Control Indicator Field CIF 0**

  CIF fields are used to call out which fields are included in the packet. Bit 30 is set to 1, indicating the inclusion of the Reference Point field, bit 21 is set to 1, indicating the inclusion of the Sample Rate field, bit 20 is set to 1, indicating the inclusion of the Timestamp Adjustment field, and bit 2 is set to 1, indicating the inclusion of the CIF 1 field.

- **Word 13: Control Indicator Field CIF 1**

  The Buffer Size field inclusion is called out by bit 1 in the CIF 1 field. This is the only bit set in the CIF 1 field.

- **Word 14: Reference Point Field**

  The Reference Point is the point in the signal path that the Flow Control Packet is conveying timing information about. See Appendix 5.2 for more detail.

- **Words 15-16: Sample Rate Field**

  The sampling rate of the samples in the Signal Data packets which can be set. This Sample Rate shall correspond to the Sample Rate in the associated Context Packet.

- **Words 17-18: Timestamp Adjustment Field**

  With the presence of Prologue Timestamp in the associated Context Packet and the inclusion of the Reference Point field and this Timestamp Adjustment field in this Control Packet, the value in the Timestamp adjustment field should be a 64-bit two's-complement value in femtoseconds, representing the signal delay between the Reference Point called out in this Control Packet and the SID location. On the transmit path, this value will generally be positive, and on the receive path, it will generally be negative. Appendices 5.1 and 5.2 describe the relationship between the signal timing, SID and Reference Point locations, and the Timestamp Adjustment.

- **Words 19-21: Buffer Size Field**

  The Buffer Size field comprises three 32-bit words. The subfield in Word 19-20 is a 64-bit unsigned integer field that describes the size of the stream sink's buffer in bytes. The 16 MSBs of the second subfield (Word 21) are reserved and are set to zero. The next most significant eight bits are designated in VITA 49.2 as the Buffer Level sub-field, and the eight least significant bits are the Buffer Status sub-field. In this Packet Class, the four most significant bits of the Buffer Status sub-field are used as an extension to the Buffer Level sub-field, making up a 12-bit sub-field indicating the fill-level of the buffer. A value of 0xFFF shall indicate a full buffer, a value of 0x000 shall indicate an empty buffer, with intermediate values distributed proportionately to the fill level. The value to be placed in this sub-field shall be an average of the buffer fill level during the interval between the previous issuance of a Timing Flow Control Packet and the present one (the "current interval"). The method of averaging (e.g., rolling average, exponential average, etc.) should be determined by the manufacturer of the equipment.

  The remaining four bits are used for discrete status.

  Bit 3 of Word 21 is the Buffer Overflow indicator and is set whenever an overflow occurs at any point within the current interval.

Bit 2 of Word 21 is the Nearly Full indicator and is set whenever the buffer level exceeds the nearly full threshold at any point within the current interval. For Information Class 0x0002, the Nearly Full and Nearly Empty thresholds are pre-assigned or set by non-VRT means.

Bit 1 of Word 21 is the Nearly Empty indicator and is set whenever the buffer level falls below the nearly empty threshold at any point within the current interval.

Bit 0 of Word 21 is the Underflow indicator and is set whenever a buffer underflow occurs at any point within the current interval.

4.3.2 Packet Class 0x0006, Real Time TSF Timing Flow Control

Timing Flow Control Packet Class		
Class Name: " Real Time TSF Timing Flow Control", Code 0x0006		
Packet Stream Purpose: "To provide timing and buffer level information to permit synchronization of upstream devices"		
Packet Header		
Parameter	**Selected Options**	**Comments**
Packet Type	Control Packet with Stream ID	Conveys timing and buffer fill and status information for paired Data Stream
Packet Size	21 words	
Stream Identifier	Yes	Matches SID for paired Data Stream
Class ID	Present	OUI is 0x6A621E Packet Class Code is 0x0006
Integer Timestamp	Present	Routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate. May be periodically re-synchronized to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded reset to external reference.
Fractional Seconds Timestamp	Real Time (picoseconds)	
Context Fields		
Parameter	**Selected Options**	**Comments**
CAM Field	Present	
Message ID	Present	Sequentially assigned to the series of Control Packets issued by a Controller device
Controllee ID	Present	Pre-assigned value identifying each Controllee device in a system

Controller ID	Present	Pre-assigned value identifying each Controller device in a system
Control Indicator Field CIF 0	Present	32-bit word indicating which fields are present in the Command Packet; in the case of this Flow Control Packet, indicates the presence of the Reference Point field, the Timestamp Adjustment field, and the CIF1 field
Control Indicator Field CIF 1	Present	32-bit field indicating which fields are present in the Command Packet; in the case of this Flow Control Packet, indicates the presence of the Buffer Size (3-word) Field
Reference Point Field		
Reference Point	Present	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
Sample Rate Field		
Sample Rate	Present	64-bit field indicating the digital sample rate in Hz. Unsigned integer with the radix point to the right of bit 20 in the second 32-bit word of the 64-bit field. Only integer Hz sample rates are permitted, that is, all bits to the right of the radix point must be zero.
Timestamp Adjustment Field		
Timestamp Adjustment	Present	64-bit field indicating the signal delay in femtoseconds between the Reference Point called out in this packet and the SID Location called out in the associated Context Packet. This field is formatted as a signed integer
Buffer Size Fields		
Buffer Size	Present	64-bit field indicating the size of the Buffer in bytes. This field is formatted as an unsigned integer
Buffer Level/Buffer Status	Present	The 16 MSBs of this field are reserved. The next 8 MSBs comprise the Buffer Level sub-field. The four MSBs of the Buffer Status field are used to extend the Buffer Level sub-field to 12-bit resolution. The Buffer Level subfield represents an average of the buffer fill level where the details of the averaging are left to the implementation. The four LSBs of the Buffer Status sub-field provide discrete status indicators. In the description, immediately following, of the four status indicator bits, the term «current interval» shall refer to the interval between the issuance of the previous Flow Control Packet and the issuance of the present Flow Control Packet.

		• The Buffer Overflow (set to «1» whenever a buffer overflow occurs during the current interval). • The Nearly Full indicator (set to «1» if the Buffer Level exceeds the nearly full threshold during the current interval). • The Nearly Empty indicator (set to «1» if the Buffer Level falls below the nearly empty threshold during the current interval). • The Buffer Underflow (set to «1» if the Buffer underflows during the current interval).

Table 21. Packet Class 0x0006, Real Time TSF Timing Flow Control

The packet format is shown in Table 22.

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	Word #
0	1	1	0	1	0	0	0	TSI		1	0	Packet Count				Packet Size (21 Words)																1
Stream Identifier																																2
0	0	0	0	0	0	0	0	24-Bit DIFI CID (0x6A621E)																								3
Information Class (number of incorporating class)																Packet Class= 0x0006																4
Integer Seconds Timestamp (per TSI field)																																5
Fractional Seconds Timestamp (Real Time [picoseconds])																																6
																																7
1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13
Reference Point (Default = 0x00000064)																																14
Sample Rate																																15
																																16
Timestamp Adjustment (femtoseconds)																																17
																																18
Buffer Size																																19
																																20
Reserved																Level												OF	NF	NE	UF	21

Table 22. Packet Class 0x0006 Format, Real Time TSF Timing Flow Control

- **Word 1: Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x6 which indicates a Command Packet with a stream ID.
  - **Bit 27: Class Identifier**

    This bit must be set to 1 which indicates the optional Class Identifier field is included. See section 5.1.3 of the VITA 49.2 specification [2] for] for more information.

  - **Bits 26 – 24: Control vs Acknowledge indicators**

    These bits must be set to 0x0 for a Control Packet (that is not a cancellation packet).

  - **Bits 23 – 22: Timestamp Integer**

    The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 7.

  - **Bits 21 – 20: Timestamp Fractional**

    The TSF field indicates the type of fractional seconds and is set for Real Time (picoseconds) (0x2).

  - **Bits 19 – 16: SeqNum**

    This 4-bit sequence number is incremented modulo 16 for each sequential Flow Control Packet.

  - **Bits 15 – 0: Packet Size**

    The number of 32-bit words in the packet including the header and any optional fields. Fixed at 21 words for the Timing Flow Control packet.

- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream or Command Packet Stream, they will share Stream IDs. See Appendix 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.

  The SID location must be documented, and in this Standard, the SID location shall be the digital interface of the IFC, that is the point of generation of samples out of the ADC in the receive path direction and the point of consumption of samples within the DAC in the transmit path direction. If in addition to an IFC the system includes devices with both digital input and digital output (e.g., a digital combiner or splitter), the SID(s) for streams feeding such devices in the transmit direction should be at the point at which the samples are consumed, at the downstream end of the digital link.

- **Words 3,4: Class Identifier**

  - **Bits 31 – 27: Padding Bits**

    The pad bit count is set to zero.

  - **Bits 26 – 24: Reserved Bits**

    The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5.

  - **Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value

    (0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E.

  - **Bits 31 – 16: Information Class Code**

    This Packet Class was originally generated for use with Information Class 0x0003 but may also be used with subsequently defined Information Classes that require a Real Time (picoseconds) TSF based Flow Control Packet.

  - **Bits 15 – 0: Packet Class Code**

    The Packet Class for this packet is 0x0006.

- **Word 5: Integer-seconds Timestamp**

  The Integer Seconds Timestamp field will nominally be incremented each time the Fractional Timestamp field reaches the value of 10^{12} picoseconds. Upon issuance of an external reset signal, the Integer-seconds Timestamp shall be reset to the external source specified in the header. The seconds since epoch for the selected time reference (UTC, GPS or POSIX). Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Words 6,7: Fractional-seconds Timestamp**

  The value in this field reflects the number of picoseconds since the incrementation or reset of the integer seconds. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Word 9: Message ID**

  Each Timing Flow Control Packet corresponding to any specific Stream ID shall be issued with a unique sequential 32-bit Message ID

- **Word 10: Controller ID**

  In systems having multiple controller devices, each shall be assigned a distinct 32-bit Controller ID. This value should default to 0x00000000 (see Recommendation 4.3.2-1).

  Recommendation 4.3.2-1

  In systems not requiring distinct Controller IDs (e.g., systems having a single controller device), a Controller ID of 0x00000000 should be used.

- **Word 11: Controllee ID**

  In systems having multiple controllee devices, each shall be assigned a distinct 32-bit Controller ID if there is a requirement that each be controlled separately. This value should default to 0x00000000 (see Recommendation 4.3.2-2).

  Recommendation 4.3.2-2

  In systems not requiring distinct Controllee IDs (e.g., systems having a single controllee device, or systems in which all controllee devices are to respond identically), a Controllee ID of 0x00000000 should be used.

- **Word 12: Control Indicator Field CIF 0**

  CIF fields are used to call out which fields are included in the packet. Bit 30 is set to 1, indicating the inclusion of the Reference Point field, bit 21 is set to 1, indicating the inclusion of the Sample Rate field, bit 20 is set to 1, indicating the inclusion of the Timestamp Adjustment field, and bit 2 is set to 1, indicating the inclusion of the CIF 1 field.

- **Word 13: Control Indicator Field CIF 1**

  The Buffer Size field inclusion is called out by bit 1 in the CIF 1 field. This is the only bit set in the CIF 1 field.

- **Word 14: Reference Point Field**

  The Reference Point is the point in the signal path that the Flow Control Packet is conveying timing information about. See Appendix 5.2 for more detail.

- **Words 15-16: Sample Rate Field**

  The sampling rate of the samples in the Signal Data packets which can be set. This Sample Rate shall correspond to the Sample Rate in the associated Context Packet.

- **Words 17-18: Timestamp Adjustment Field**

  With the presence of Prologue Timestamp in the associated Context Packet and the inclusion of the Reference Point field and this Timestamp Adjustment field in this Control Packet, the value in the Timestamp adjustment field should be a 64-bit two's-complement value in femtoseconds, representing the signal delay between the Reference Point called out in this Control Packet and the SID location. On the transmit path, this value will generally be positive, and on the receive path, it will generally be negative. Appendices 5.1 and 5.2 describe the relationship between the signal timing, SID and Reference Point locations, and the Timestamp Adjustment.

- **Words 19-21: Buffer Size Field**

  The Buffer Size field comprises three 32-bit words. The subfield in Words 19-20 form a 64-bit unsigned integer that describes the size of the stream sink's buffer in bytes. The 16 MSBs of the second subfield (Word 21) are reserved and are set to zero. The next most significant eight bits are designated in VITA 49.2 as the Buffer Level sub-field, and the eight least significant bits are the Buffer Status sub-field. In this Packet Class, the four most significant bits of the Buffer Status sub-field are used as an extension to the Buffer Level sub-field, making up a 12-bit sub-field indicating the fill-level of the buffer. A value of 0xFFF shall indicate a full buffer, a value of 0x000 shall indicate an empty buffer, with intermediate values distributed proportionately to the fill level. The value to be placed in this sub-field shall be an average of the buffer fill level during the interval between the previous issuance of a Timing Flow Control Packet and the present one (the "current interval"). The method of averaging (e.g., rolling average, exponential average, etc.) should be determined by the manufacturer of the equipment.

  The remaining four bits are used for discrete status.

  Bit 3 of Word 21 is the Buffer Overflow indicator and is set whenever an overflow occurs at any point within the current interval.

Bit 2 of Word 21 is the Nearly Full indicator and is set whenever the buffer level exceeds the nearly full threshold at any point within the current interval. For Information Class 0x0002, the Nearly Full and Nearly Empty thresholds are pre-assigned or set by non-VRT means.

Bit 1 of Word 21 is the Nearly Empty indicator and is set whenever the buffer level falls below the nearly empty threshold at any point within the current interval.

Bit 0 of Word 21 is the Underflow indicator and is set whenever a buffer underflow occurs at any point within the current interval.

5. STREAM AND REFERENCE POINT ID

5.1 STREAM IDENTIFIER (SID) AND SID LOCATION

The Stream Identifier (SID) has three distinct functions:

1. To indicate that a particular Data, Context, or Command Packet is part of a sequence of packets of the same type bearing the same Stream ID
2. To indicate which Context or Command Packet streams are associated with which Data Packet streams
3. To define a specific location (generally the source or destination of the stream) referred to as the SID location, which is used in conjunction with the time stamping.

The actual number selected for the Stream ID is an arbitrary 32-bit number which can be selected at run time. In the DIFI Standard, the inclusion of the Stream ID is mandatory. The DIFI Standard also mandates the inclusion of the Integer Seconds Timestamp and the Fractional Seconds Timestamp fields in the Data Packets. Together, these two fields are referred to as the “Prologue Timestamp”. Generally, the Prologue Timestamp corresponds to the time at which the first sample in a Data Packet is present at the SID location (the first sample will be present at the Reference Point at a time which is the sum of the Prologue Timestamp value and the Timestamp Adjustment – see 5.2 for more details). Alternatively, one may think of the SID location as the point in the system at which the Prologue Timestamp is referenced.

The DIFI Standard mandates the SID location based on system configuration. There are three general categories of devices, and the SID location depends on the category:

1. For digital streams sourced by an analog to DIFI stream converter, the SID location shall be the point of generation of digital samples within the analog to digital converter, illustrated in Figure 8 and Figure 9.
2. For digital streams having a sink device implementing a DIFI stream to analog signal conversion, the SID location shall be the point of consumption of the samples within the digital to analog converter, illustrated in Figure 10 and Figure 11.
3. For digital streams having an intermediate DIFI stream inputs and outputs, the SID location shall be at the point of generation of the digital samples if the device is in the receive path (e.g., as a splitter would most typically be) and shall be at the point of operation on the samples – e.g., the point at which samples are combined in a combiner, subsequent to any buffering – if the device is in the transmit path (e.g., as a combiner would most typically be). This is illustrated in Figure 12 and Figure 13

For the IF signal replication application (also known as “bookend”) in which there is an IF-DIFI device sourcing the digital signal stream and a DIFI-IF device sinking the same stream with the purpose of replicating the original IF signal at a remote location, the SID location shall be at the point of generation of the digital samples within the category (i) device. This is illustrated in Fig. Figure 14.

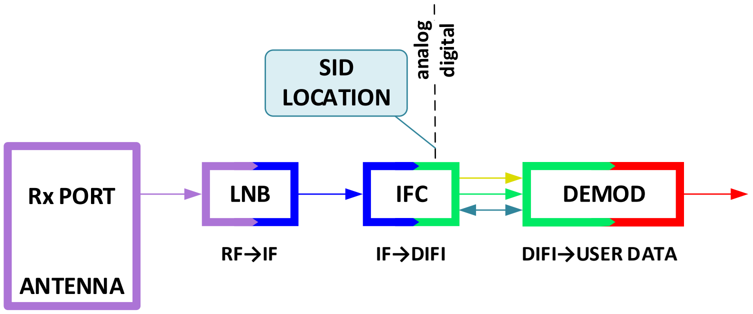


Figure 8.SID location – analog IF to DIFI

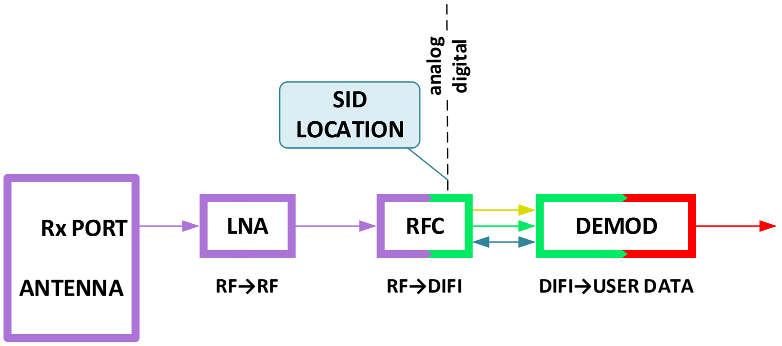


Figure 9.SID location – analog RF to DIFI

Figure 8 illustrates of SID locations for typical receive path applications with a conversion device that converts from an analog IF signal to a DIFI digital signal stream, whilst Figure 9 illustrates a conversion device that converts from an analog RF signal to a DIFI digital signal stream.

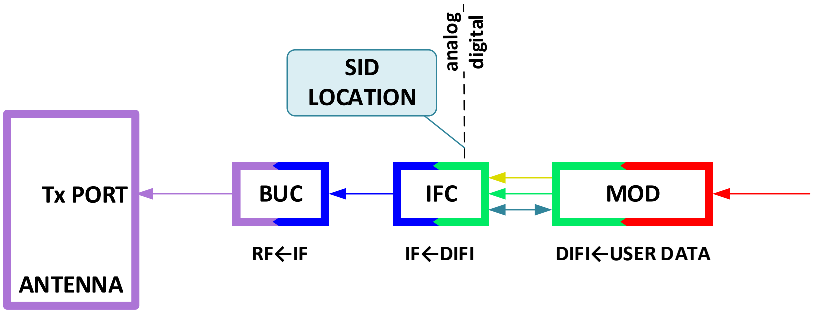


Figure 10. SID location –DIFI to analog IF

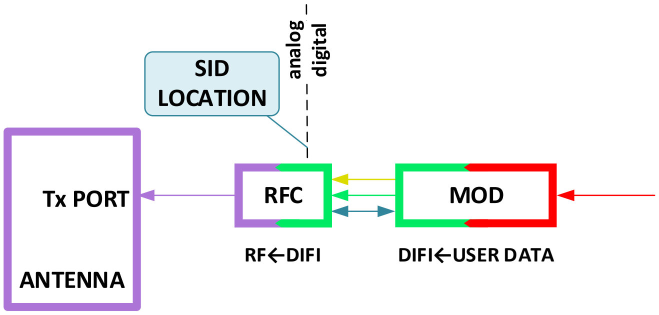


Figure 11. SID location –DIFI to analog RF

Figure 9 illustrates the SID location for a transmit path using a conversion device that converts a DIFI stream to an analog IF signal that is subsequently upconverted to the RF transmission frequency by an analog block upconverter. Figure 10 illustrates the SID location for a transmit path that uses a device that converts a DIFI stream directly to an analog RF output at the RF transmission frequency.

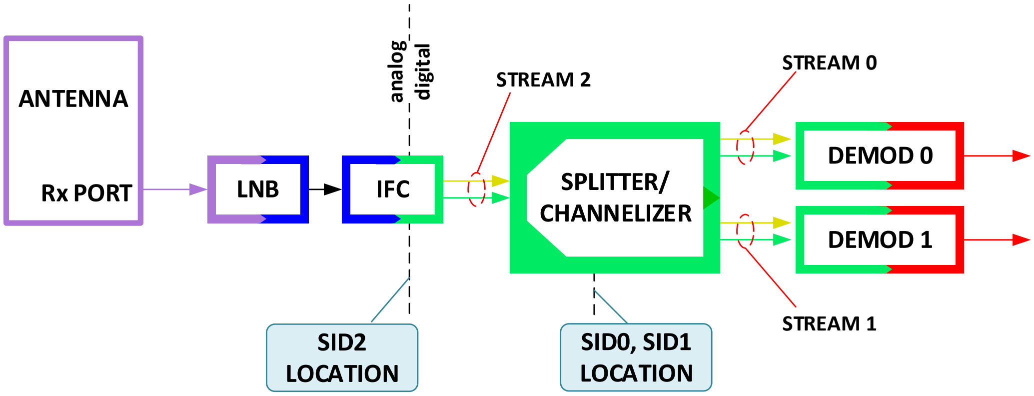


Figure 12. SID locations for category (iii) devices on the receive path.

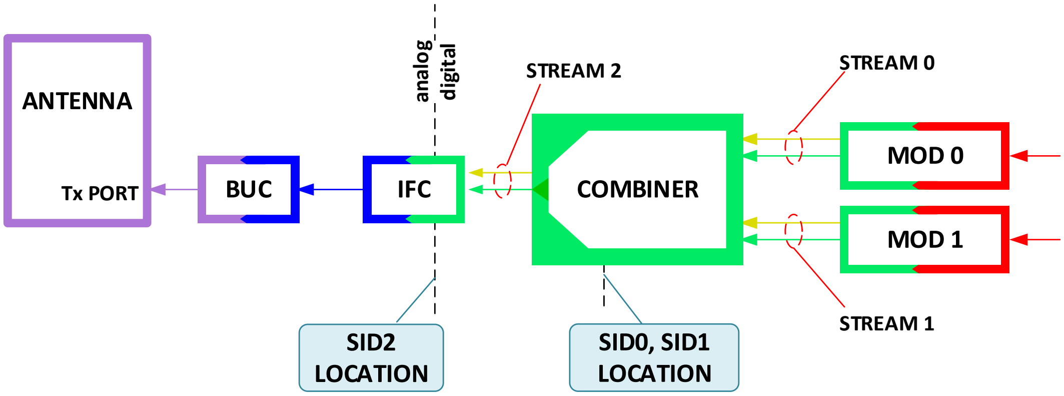


Figure 13. SID locations for category (iii) devices on the transmit path.

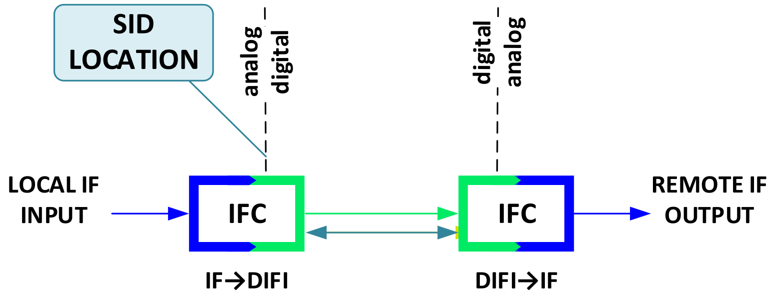


Figure 14. SID location for IF signal replication at a remote location

5.2 REFERENCE POINT IDENTIFIER AND TIMESTAMP ADJUSTMENT

The Reference Point Identifier Field is used within VITA 49.2 and the DIFI Standard to identify a location, other than the SID location, within the system, to which certain parameters – e.g., Timestamp Adjustment, Reference Level, and various reference frequencies – pertain. The Reference Point Identifier field, the Reference Level field, the various reference frequency fields, and the Timestamp Adjustment field, are mandatory within the DIFI Standard.

The Standard recommends that in both the transmit and receive directions, systems having a converter that operates between an analog IF signal and a DIFI digital stream should have the analog input or analog output of the conversion device referred to as Reference Point 100 (0x0064). The analog output of the RF device on the transmit path and the analog input to the front-end RF device on receive should be referred to as Reference Point 75 (0x004B). For systems having a well-defined input or output port at the antenna feed, this Reference Point should be referred to as Reference Point 25 (0x0019) if it is to be used.

The Reference Level field refers to the analog value in dBm that is present at the Reference Point. The IF Reference Frequency field indicates the frequency at Reference Point 100 (as defined above) if such a signal point is well-defined and accessible. The RF Reference Frequency indicates the frequency at Reference Point 75 (as defined above).

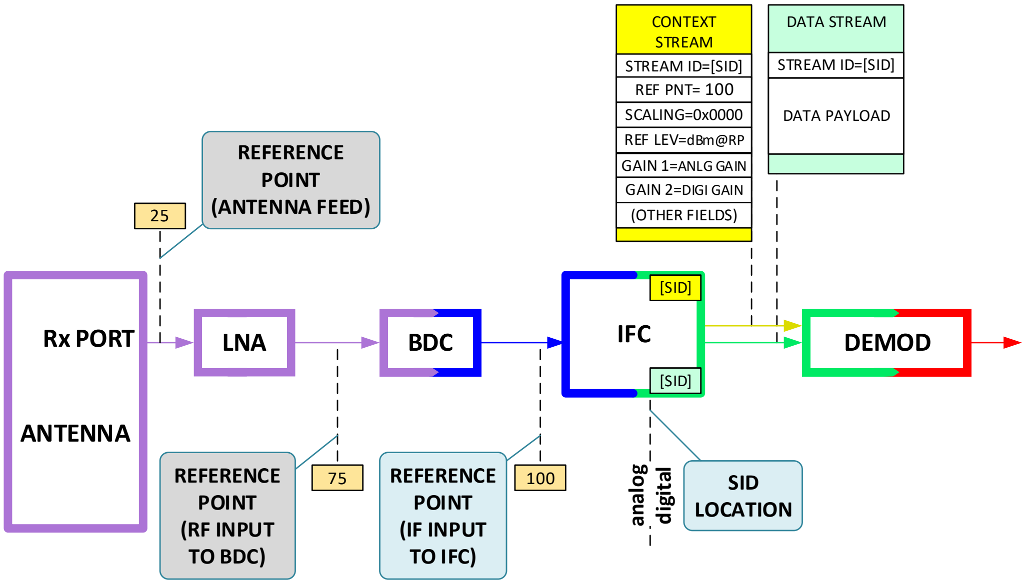


Figure 15. Receive Reference Points Using an IFC

Figure 15 illustrates the receive path using an IFC. Reference Points are labeled, Reference Point 100 (IF input to IFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (100), Reference Level (analog signal level in dBm at Reference Point that results in a full-scale sine wave output if DIFI payload), pre-conversion analog gain and post conversion digital gain.

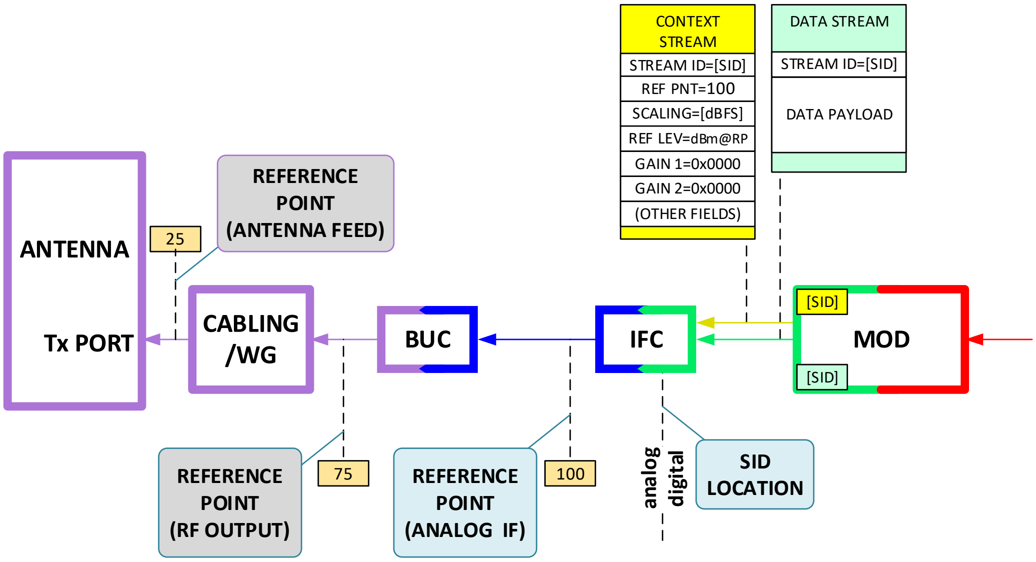


Figure 16. Transmit Reference Points Using an IFC

Figure 16 illustrates the transmit path using an IFC. Reference Points are labeled, Reference Point 100 (IF output from IFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (100), Reference Level 1 (analog signal level in dBm at Reference Point that results from a full-scale sine wave input at the DIFI input).

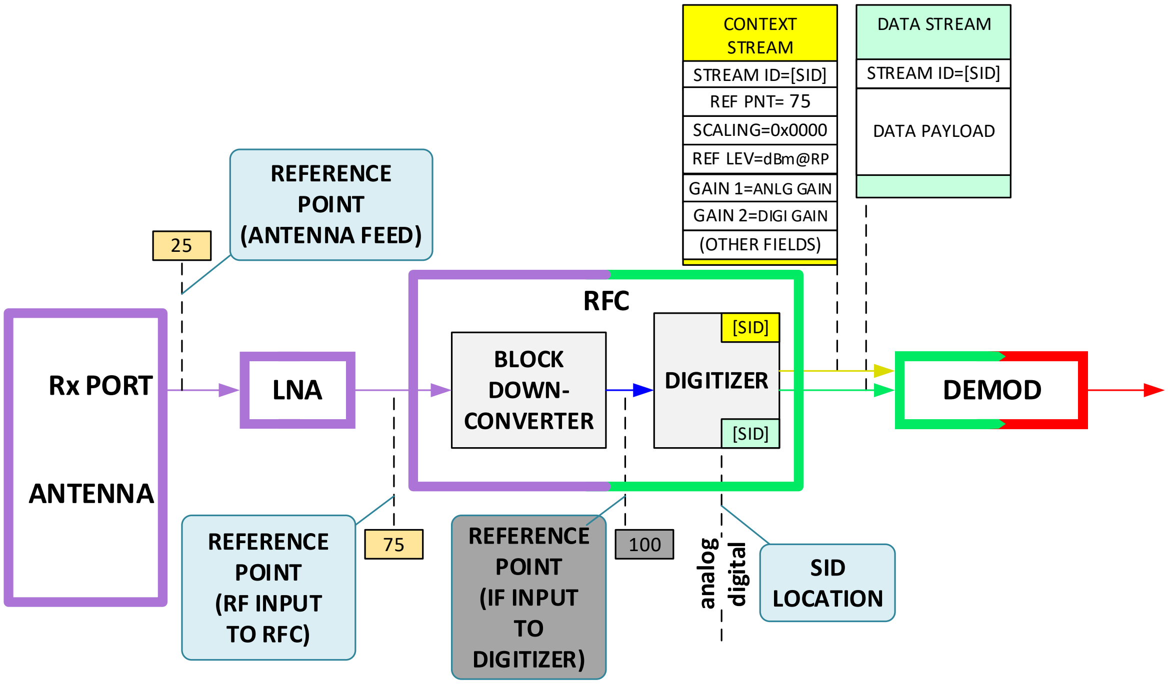


Figure 17. Receive Reference Points Using an RFC

Figure 17 illustrates receive path using an RFC. Reference Points are labeled, Reference Point 75 (RF input to RFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (75), Reference Level (analog signal level in dBm at Reference Point that results in a full-scale sine wave output if DIFI payload), pre-conversion analog gain and post conversion digital gain.

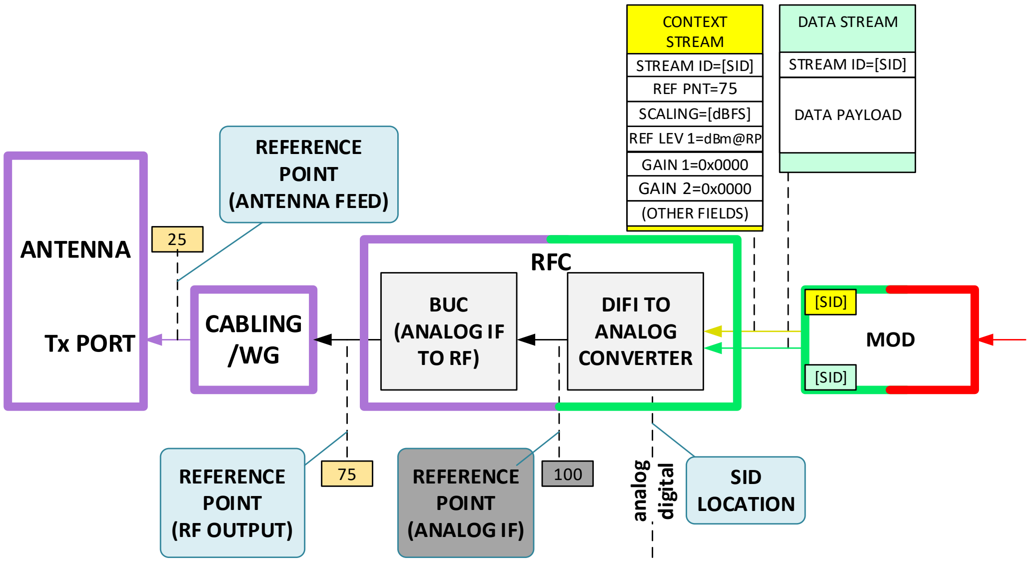


Figure 18. Transmit Reference Points Using an RFC

Figure 18 illustrates the transmit path using an RFC. Reference Points are labeled, Reference Point 75 (RF output from RFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (75), Reference Level 1 (analog signal level in dBm at Reference Point that results in a full-scale sine wave output if DIFI payload).

Figure 19 illustrates a configuration using a DIFI stream to DIFI Stream device in addition to an IFC. Reference Point 100 is used by the Combiner output stream to indicate the analog level at the IFC output. Reference Level for the other two streams has no meaning, but Reference Point and SID location can be used for timing and synchronization purposes.

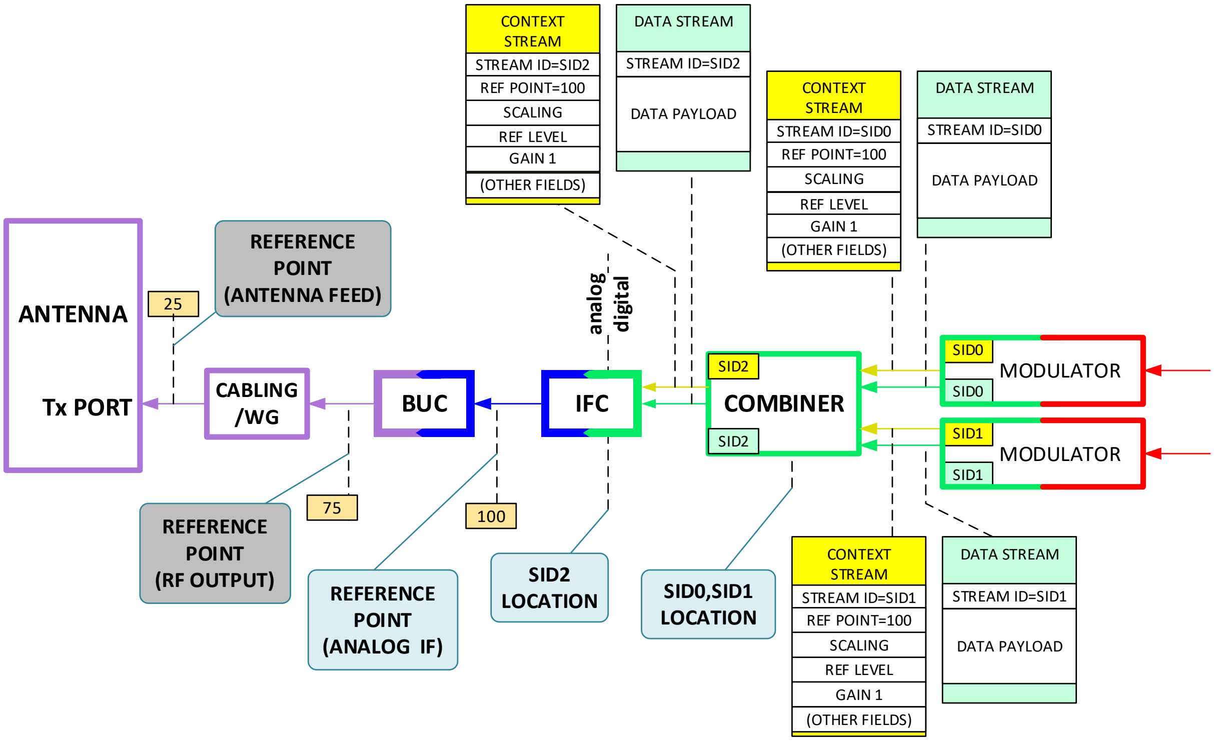


Figure 19. Configuration using a DIFI stream to DIFI Stream device in addition to an IFC.

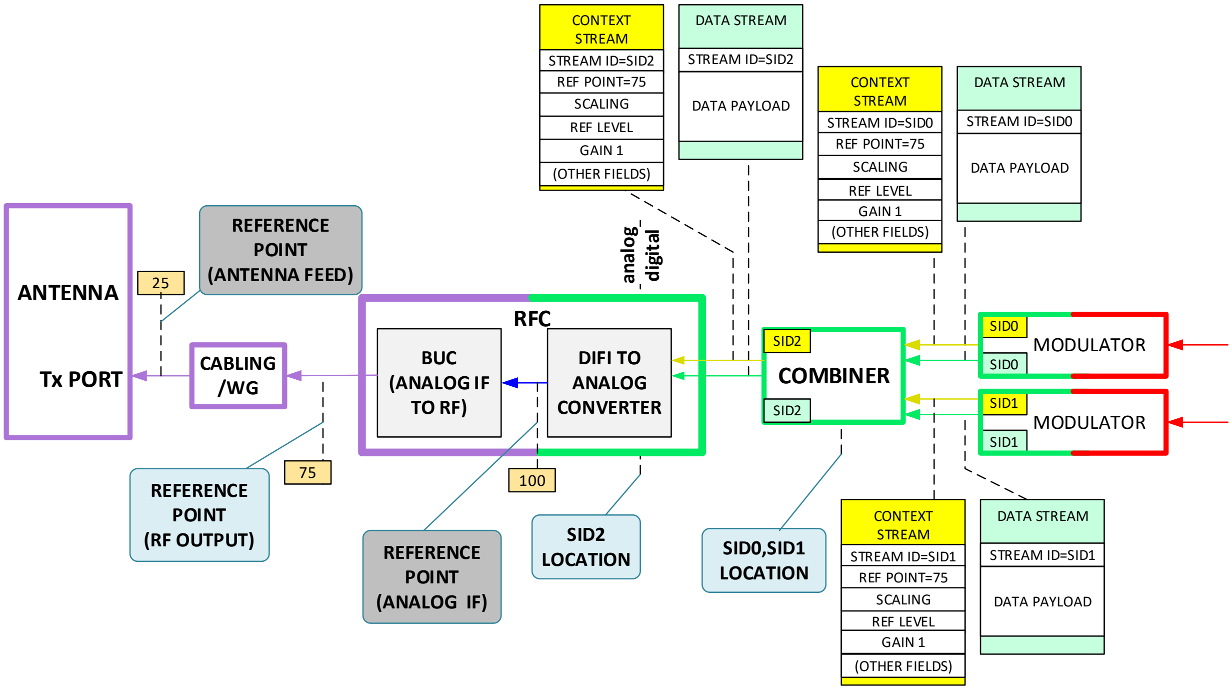


Figure 20. Configuration using a DIFI stream to DIFI Stream device in addition to an RFC.

Figure 20 illustrates a configuration using a DIFI stream to DIFI Stream device in addition to an RFC. Reference Point 75 is used by the Combiner output stream to indicate the analog level at the RFC output. Reference Level for the other two streams has no meaning, but Reference Point and SID location can be used for timing and synchronization purposes.

The Timestamp Adjustment field characterizes the physical signal delay between the Reference Point and the SID in a particular physical implementation. This field is in femtoseconds and is generally a negative value on the receive path and a positive value on the transmit path. Figure 21 illustrates Reference Point locations and associated field values for various configurations.

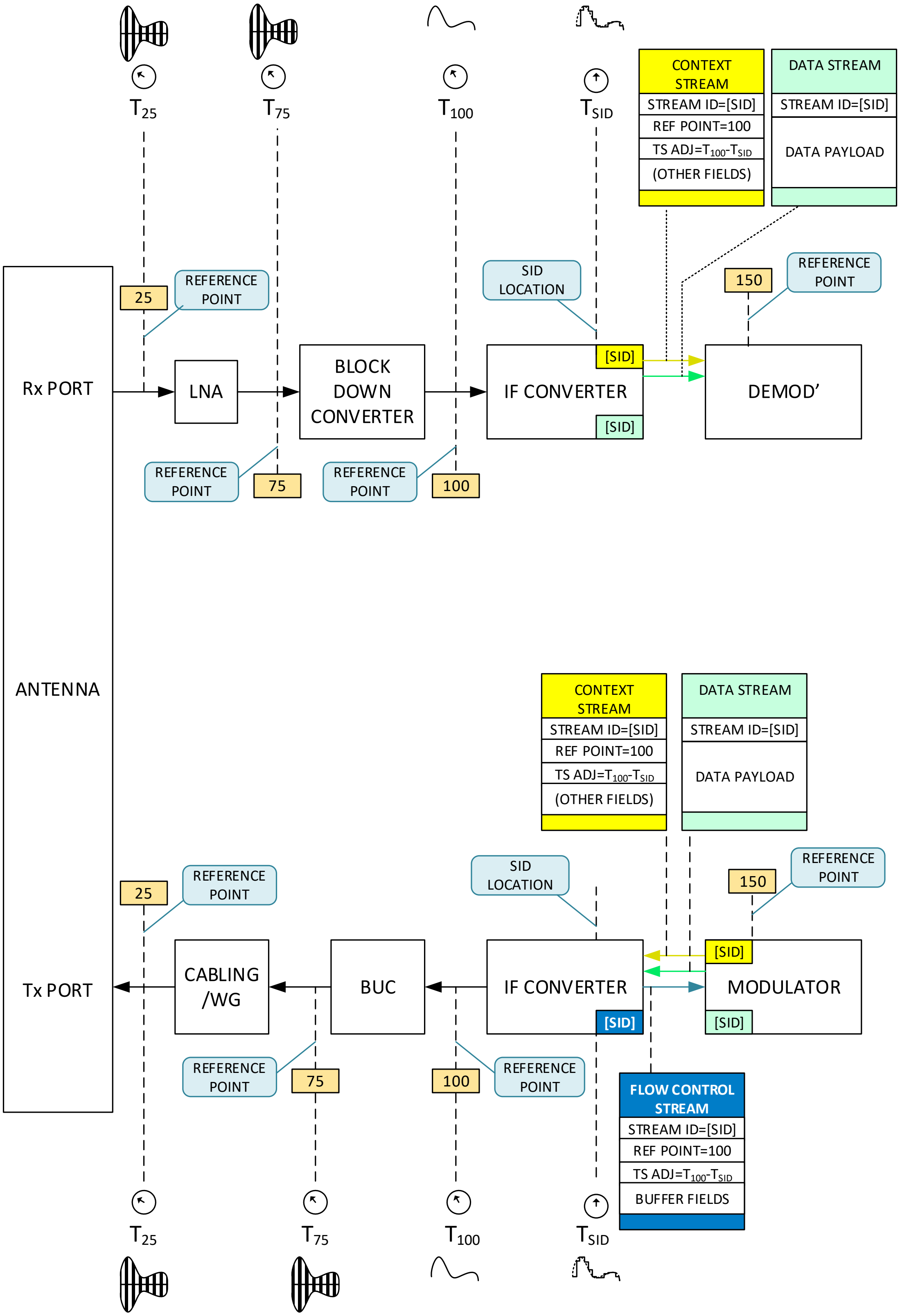


Figure 21. Time values at various reference points

Figure 21 Illustration of time values at various Reference Points. In this illustration, Reference Point 100 is used, so that the Timestamp Adjustment is given by T100-TSID.

6. APPENDIX - DIFI DEFINITIONS AND USE CASES

This appendix is intended to help align the DIFI community on a shared understanding of the terminology in use and how this shared vocabulary can help make the standard a widespread, useful, and perhaps even effective tool in making the flexible Digital IF-based interoperable vision into a reality. To that end, the following sections lay out definitions to serve as the basis for discussion; high level descriptions of how the previously described information and packet classes can be useful; and deep dives into implementation to illustrate the nuts and bolts of the kind of system design that the DIFI spec enables.

6.1 DEFINITIONS

DIFI Device: Any hardware, firmware, or software that creates a Source or Sink using the DIFI protocol.

The term is intended to be flexible and able to describe both hardware-centric and software-only systems.

Examples: Modems, combiners, channelizers/splitters, recorders, digitizers, etc.

DIFI Use Case: The operational use of a DIFI device for the generation, transmission, and/or consumption of a Packet Stream.

Examples: analog-to-DIFI conversion, recording and playback of DIFI streams, samples-to-user-data conversion, combiner/divider

Example diagrams with a DIFI device (defined below) demonstrating each listed use case:

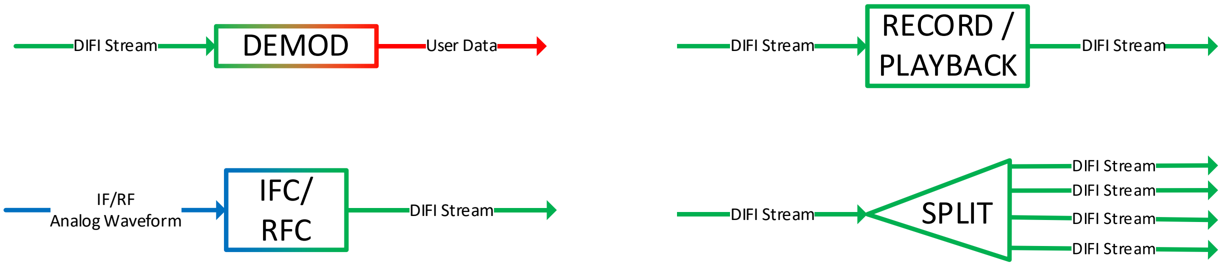


Figure 22. Example DIFI Devices

DIFI Implementation: A DIFI implementation is anything that implements one or more DIFI use cases. From the perspective of the standard, anything that uses DIFI packets to carry out a system design is an implementation.

Examples: inter-facility link (IFL), gateway, terminal, STAR network

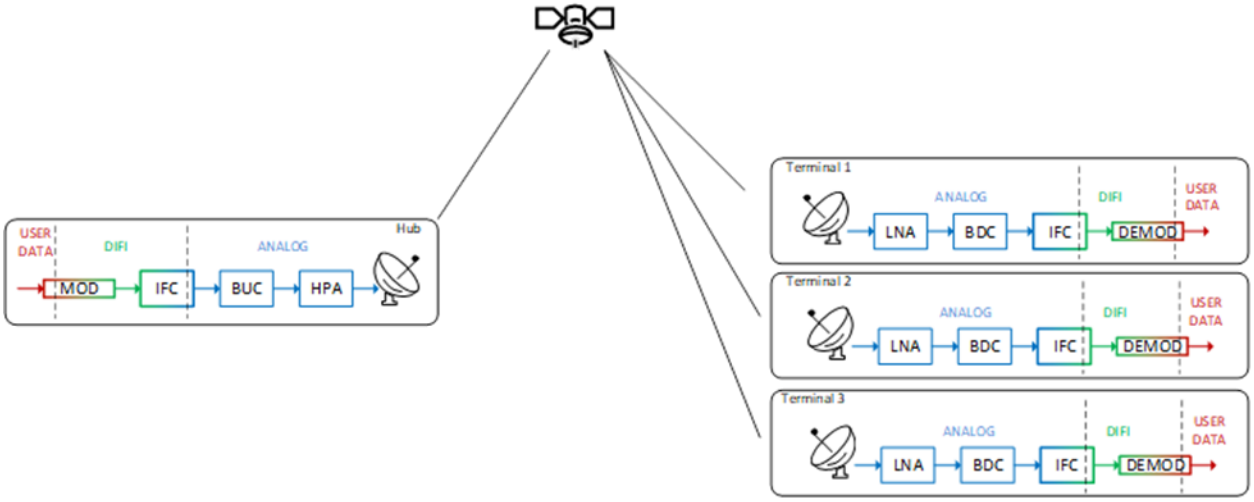


Figure 23. Example DIFI Application

DIFI Application: A DIFI application refers to the content of the DIFI sample stream.

This is probably the broadest category and encompasses the overall communication methods/systems that are currently in use (and may be developed in the future) that the DIFI standard needs to enable but by definition cannot predict. Applications drive the design of the information and packet classes because they use Digital IF in the real world. A readily available example of this is the driver for Information Class 0x0002, namely the specific application of supporting an SCPC waveform as implemented in a DIFI terminal with no shared reference plane.

6.2 USE CASES

DIFI use cases involve the generation, transmission, and/or consumption of a DIFI sample stream, i.e., the movement or transformation of the Digital IF samples. In the case of the modem or IFC, this is self-explanatory, as in a modulator, user data is processed into Digital IF samples, and then the IFC transforms the digital samples into an analog waveform.

The use case of transmission may include storage and can be observed in devices such as a recorder that may also be used for playback, to move DIFI-compliant Digital IF sampling data for processing, troubleshooting, or other uses.

6.3 IMPLEMENTATIONS

Implementations, as considered by the DIFI standard, are where the rubber meets the road in terms of using DIFI to carry out a system design. The implementation diagrams and descriptions that follow are attempts to illustrate how DIFI and the particular choices made within the specification enable both simple and complex system designs.

6.3.1 Information Class 0x0000

The Basic Data Plane Structure of Information Class 0x0000, the original class described by the DIFI specification, supports a simpler data plane configuration and presumes that much of the configuration and command/control of the system in operation is done out of band. In a system with a single emitter and consumer, if a shared reference signal exists for synchronization, using the Information Class 0x0000 is a straightforward choice for data transmission. Additionally, if two-way traffic is present, i.e., two devices in a system are both emitting and consuming data, then synchronization information can be extracted from the existing traffic and the functionality provided by Information Class 0x0000 is sufficient.

An example of this second case, with two devices in a system acting as both emitters and consumers, follows here. Given a digitizer/IFC and a modem that can each share information between Tx and Rx, the modem receive side can synchronize to the ADC sample rate using the arrival rate and timestamps of received data packets. The modem's Tx and the IFC's Tx can each synchronize to the Rx side of their own device, and thus the system is synchronized.

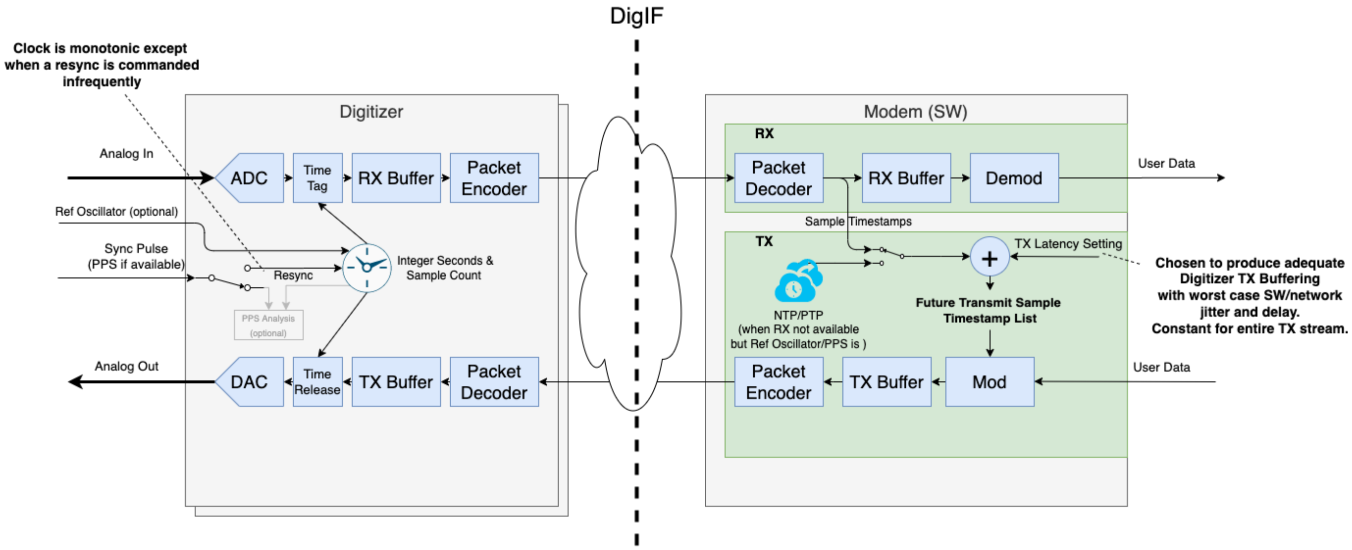


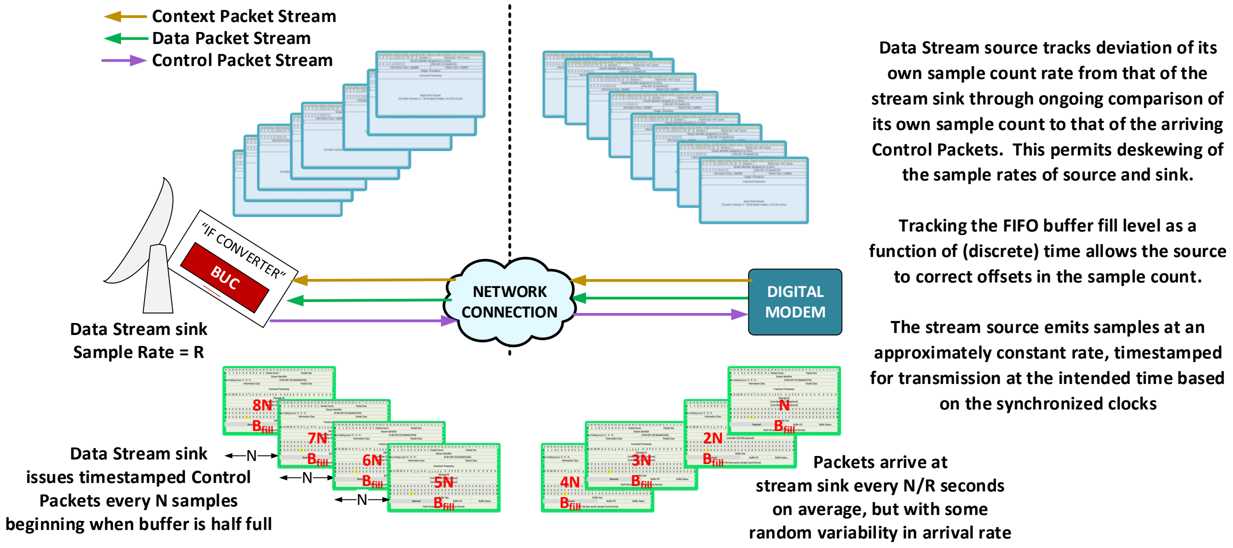
Figure 24. Implementation Class 0x0000 Example

6.3.2 Information Class 0x0002

The addition of Information Class 0x0002 to the DIFI Standard allows for a standard flow control mechanism to be used and frees up the system designer from requiring a two-way data flow for synchronization.

Three examples of the usage of this flow control mechanism follow, each of which involves data flow in the transmit direction with no shared reference plane between the source(s) of the data and its (their) destination(s).

The first example involves a single digital modulator sending data and context packets to a single IFC / BUC, where there is no shared reference plane, and indeed the two devices may be physically separated by a significant distance. In this case, the IFC is considered to be the source of timing truth, due to its hardware component, and the digital modem requires a mechanism to track the clock rate and/or the buffer depth of the IFC to ensure that data is available when it is required and that there are no discontinuities in the analog waveform. The figure below describes this implementation.



Data Stream source tracks deviation of its own sample count rate from that of the stream sink through ongoing comparison of its own sample count to that of the arriving Control Packets. This permits deskewing of the sample rates of source and sink.

Tracking the FIFO buffer fill level as a function of (discrete) time allows the source to correct offsets in the sample count.

The stream source emits samples at an approximately constant rate, timestamped for transmission at the intended time based on the synchronized clocks

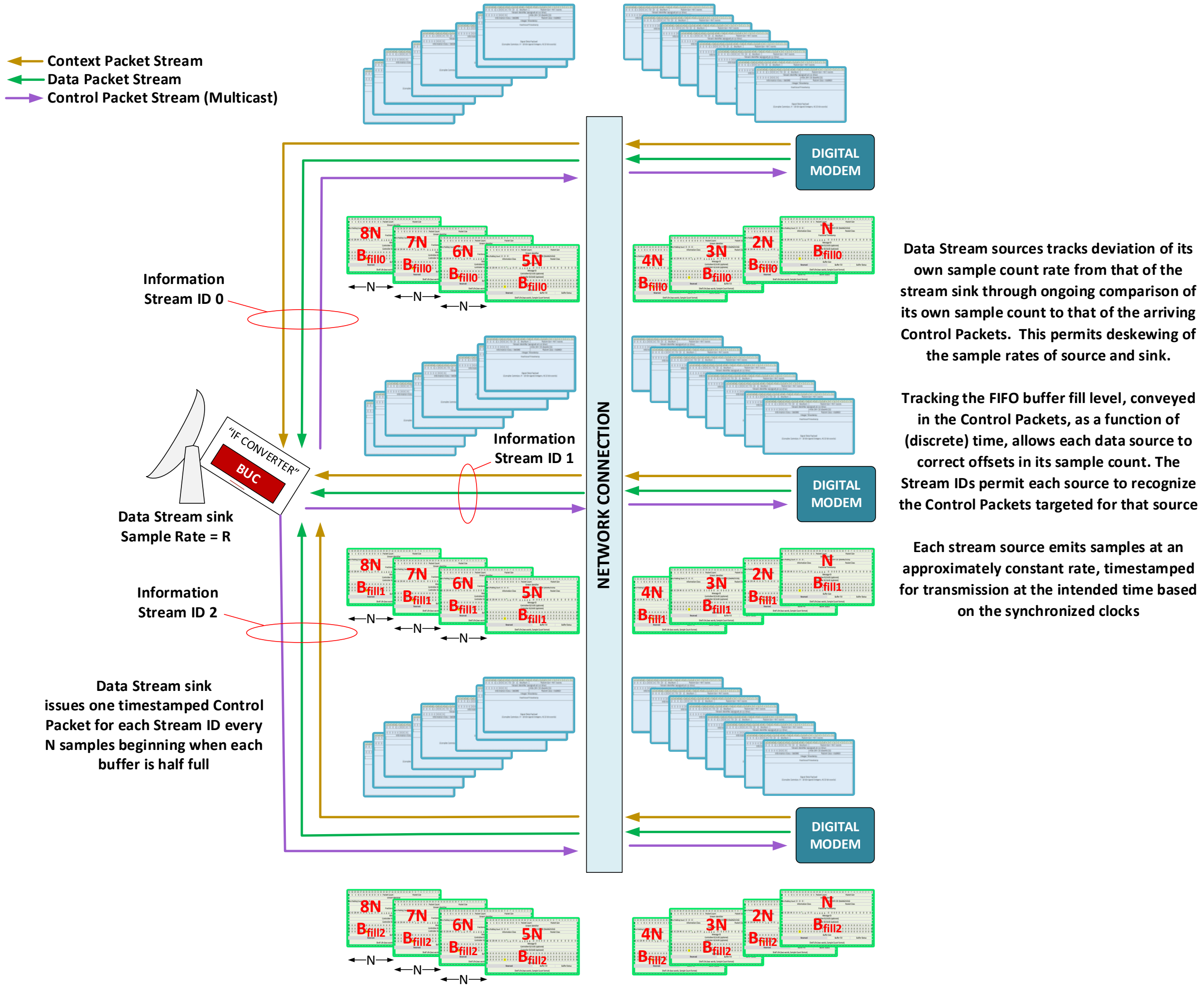
Data Stream sink issues timestamped Control Packets every N samples beginning when buffer is half full

Packets arrive at stream sink every N/R seconds on average, but with some random variability in arrival rate

Figure 25. Implementation Class 0x0002 Example – Single Source, Single Sink

The second example covers the case in which there is a single sink that serves as sample rate master receiving streams from "X" multiple sources. It makes several assumptions, including that X=3, i.e., there are three streams from three separate data stream sources; one source is running at a sample rate of 20Msamp/sec and the other two at sample rates of 10Msamp/sec; the sink has a clock that is deemed "accurate", for example, locked to a GPS source; and there is no reference plane to provide external synchronization of the three stream sources, and the sources do not have accurate clocks. The figure below describes this implementation.

It is also assumed that at the start of transmission, each of the sources is synchronized only to a loose reference (e.g., NTP). The stream sources emit their data streams by UDP multicast with data packet timestamps (integer and sample count) set at a future time chosen to account for latency, jitter, and sink buffer size. The sink would need to depacketize each of the three streams into a separate buffer, interpolate samples to bring the two "slow" streams up to the higher sample rate, and combine them (weighted sum) into an aggregate buffer. Using the proposed method, the sink would emit three separate Control Packet streams, each conveying buffer information for one of the three buffers, and each bearing the Stream ID associated with the stream feeding that buffer.



Data Stream sink issues one timestamped Control Packet for each Stream ID every N samples beginning when each buffer is half full

Data Stream sources tracks deviation of its own sample count rate from that of the stream sink through ongoing comparison of its own sample count to that of the arriving Control Packets. This permits deskewing of the sample rates of source and sink.

Tracking the FIFO buffer fill level, conveyed in the Control Packets, as a function of (discrete) time, allows each data source to correct offsets in its sample count. The Stream IDs permit each source to recognize the Control Packets targeted for that source

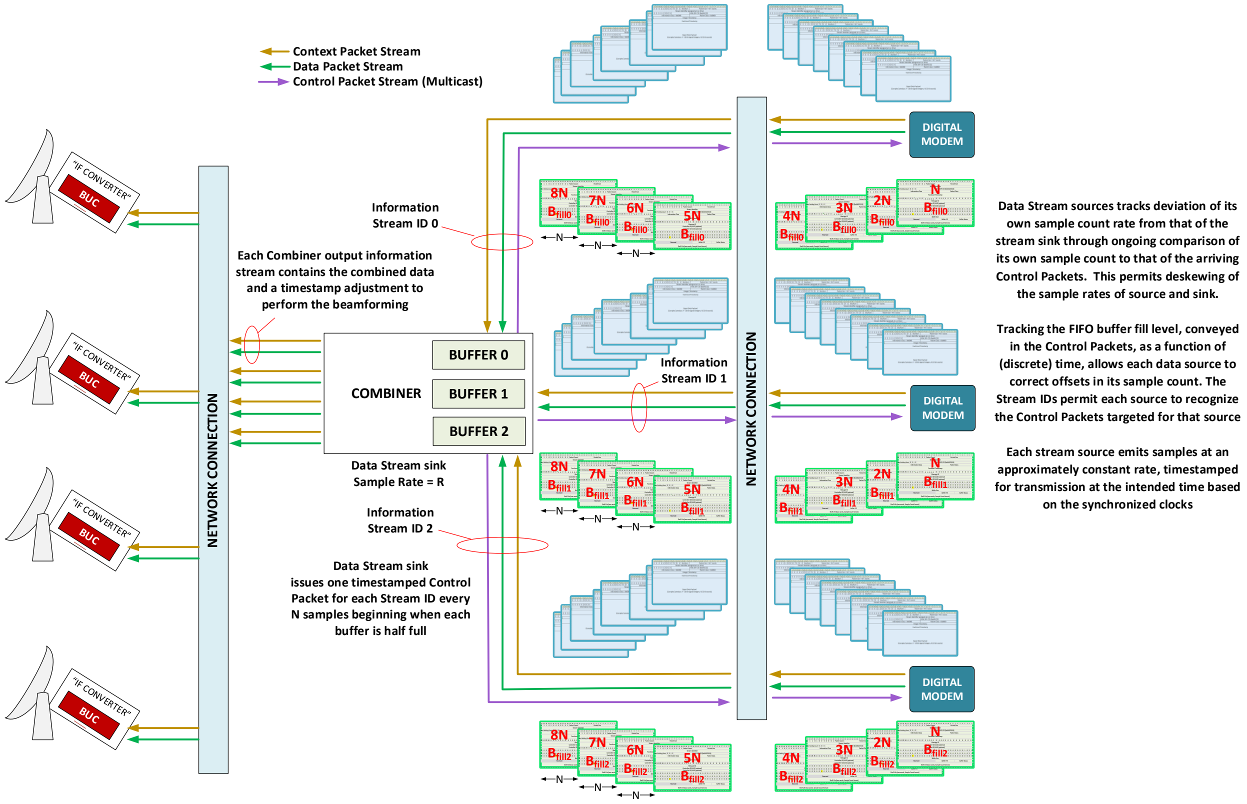
Each stream source emits samples at an approximately constant rate, timestamped for transmission at the intended time based on the synchronized clocks

Figure 26. Implementation Class 0x0002 Example – Multi-Source, Single Sink

The third example implementation of the flow control capability provided by the Information Class 0x0002 addition is a multi-source, multi-sink phased array. In this implementation, there are (as the name would suggest) multiple sinks, operating as a phased array, which has access to an accurate time reference (e.g., GPS) as well as multiple data sources. Additionally, this system design includes an intermediate combining device that accepts multiple data stream inputs from multiple sources and generates multiple output streams having appropriate phase adjustments to enable multiple sinks to operate as a phased array; this device also has access to an accurate time reference that is shared with the phase array sink devices.

It is worth noting that an extremely accurate phasing/timing is required for this implementation, requiring the use of calibrated timestamp adjustments to specific reference points (e.g., antenna feeds).

Figure 27 describes this implementation. The combiner and IFCs are synchronized to a common high-accuracy reference, the modems are synchronized to the combiner using Flow Control Packets, and each IFC responds to packets bearing the associated SID. Timestamp adjustments in the Combiner's associated output Context Packets implement beam forming timing/ phasing.



Each Combiner output information stream contains the combined data and a timestamp adjustment to perform the beamforming

Data Stream sink issues one timestamped Control Packet for each Stream ID every N samples beginning when each buffer is half full

Data Stream sources tracks deviation of its own sample count rate from that of the stream sink through ongoing comparison of its own sample count to that of the arriving Control Packets. This permits deskewing of the sample rates of source and sink.

Tracking the FIFO buffer fill level, conveyed in the Control Packets, as a function of (discrete) time, allows each data source to correct offsets in its sample count. The Stream IDs permit each source to recognize the Control Packets targeted for that source

Each stream source emits samples at an approximately constant rate, timestamped for transmission at the intended time based on the synchronized clocks

Figure 27. Implementation Class 0x0002 Example – Multi-Source, Multi-Sink

6.4 APPLICATIONS

A DIFI application refers to the content of the DIFI sample stream. As a result, applications require and consider each of the other definitions – they encompass the use cases, make use of devices, and require a system design or implementation to meet the needs of the particular application. Two ready examples of DIFI applications are SCPC waveforms, which require a constant data flow and are less susceptible to timing variation, and TDMA waveforms, which typically make use of a bursty data flow and are very sensitive to reference synchronization.

6.4.1 Supporting SCPC Waveforms with DIFI

Single channel per carrier (SCPC) waveforms use a single signal at a given frequency and bandwidth and are a common configuration on communications satellites. In this kind of system, the communications channel is constantly occupied by an uninterrupted signal and demodulators typically rely on the signal to be consistently present. These needs then drive requirements in the DIFI standard to be able to maintain consistent data traffic both in transmit and receive configurations as well as adjust sample rates and power according to the implementation design.

6.4.2 Supporting TDMA Waveforms with DIFI

Time-division multiple access (TDMA) waveforms use a single frequency channel divided up into multiple time slots to allow multiple users to share the same transmission medium by using only a part of its channel capacity. In this kind of system, the communications channel is not consistently occupied by a signal, and demodulators must be able to operate on burst data. These needs then drive requirements in the DIFI standard to be able to precisely timestamp packetized data samples as well as adjust sample rates and signal power according to the implementation design.