WHITE PAPER

An Overview of Pseudo-Random Binary Sequence

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Pseudo-Random Binary (PRBS) Feature Overview

QA engineers need to perform data integrity checks on their encapsulated packet data payload using a pseudo-random bit stream pattern (PRBS). Analysis requires that they be able to detect and report bit error rates on a per-port and per-flow basis.

The ability to flag which bits in the data payload are in error, in real time, and to automatically calculate a bit error rate (BER) value are metrics often found in acceptance tests. IxExplorer's PRBS feature provides these metrics automatically and reports these values in an organized manner.

Ixia's pseudo-random bit stream feature incorporates a polynomial to generate a 231 bit pattern. Received bits are checked for errors.

PRBS Availability

- The PRBS statistics are available on the following Ixia load modules:
- LM1000STXS4-256 Gigabit Ethernet Load Module, 4-Port Dual-PHY 10/100/1000 Mbps, SFP 1GE
- LSM1000XMSP12 Gigabit Ethernet Load Module, 12-Port Dual-PHY 10/100/1000 Mbps, SFP 1GE
- NGY 10GE load modules:
  - LSM10GXM2/4/8XP full feature set with XFP interface
  - LSM10GXMR2/4/8 reduced full feature set with XFP interface
  - LSM10GXM2/4/8S full feature set with SFP+ interface
  - LSM10GXM2/4/8 reduced full feature set with SFP+ interface
  - LSM10GXM2/4/8GBT full feature set with 10GBASE-T interface
  - LSM10GXMR2/4/8 full feature set with 10GBASE-T interface

QA engineers need to perform data integrity checks on their encapsulated packet data payload using a pseudo-random bit stream pattern (PRBS).

PRBS Measurements

The following terms are used in this document:

- PRBS – pseudo-random binary sequence
- BER – bit error rate
- BERT – bit error rate test
- PRBS BER – PRBS errored bits divided by PRBS bits received

The measurements that use the PRBS pattern are:

- Per-flow PRBS statistics
- Per-port PRBS statistics
- Frames received with header error
- Bytes received
- Error bits received
- Bit error rate

PRBS Operation

PRBS is a load module operational mode, as is latency and data integrity. PRBS must be enabled on both transmit and receive ports using the stream properties dialog.

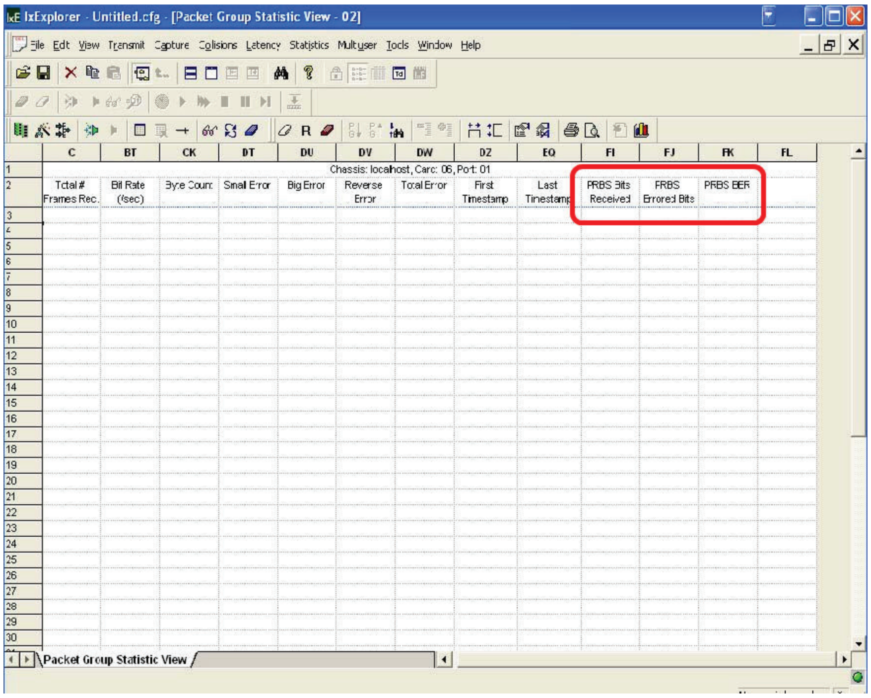
When the receive mode is set to PRBS mode, both wide packet groups and sequence checking are automatically enabled. In PRBS mode, all latency-related statistics are removed and the following per-PGID (packet group ID) statistics are added:

- PRBS bits received - the number of bits in the PRBS payload
- PRBS errored bits - the number of bits in the PRBS payload that are corrupted
- PRBS BER - the number of bits in PRBS payload that are corrupted divided by the number of PRBS received

PRBS only operates when wide packet group and auto instrumentation are enabled, making it possible for the tracking mechanisms to lock on known offsets of the Ixia packet group identification (PGID) fields in the frame.

The latency statistics report columns are replaced with PRBS statistics columns when in the PRBS mode. The packet group statistic view includes PRBS statistics highlighted in Figure 1.

PRBS is a load module operational mode, as is latency and data integrity.

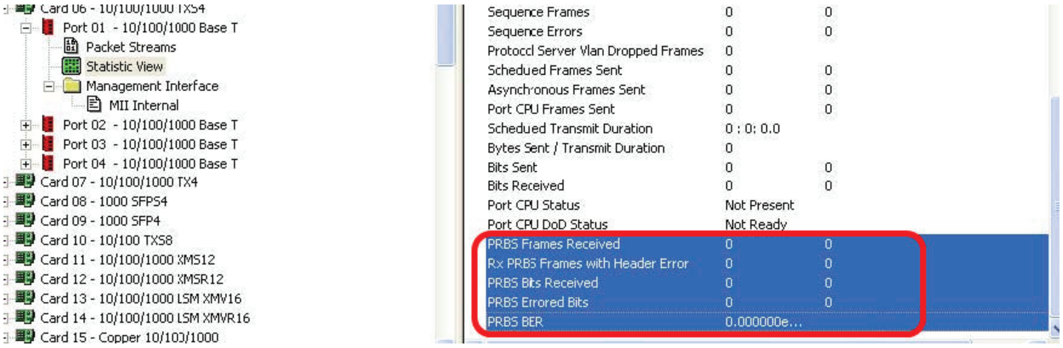

IxExplorer - Untitled.cfg - [Packet Group Statistic View - 02]
File Edit View Transmit Capture Collisions Latency Statistics Multuser Tools Window Help
Packet Group Statistic View

	C	BT	CK	DT	DU	DV	DW	DZ	EQ	FI	FJ	FK	FL
1	Chassis: localhost, Card: 06, Port: 01												
2	Total # Frames Rec.	Bit Rate (/sec)	Byte Count	Small Error	Big Error	Reverse Error	Total Error	First Timestamp	Last Timestamp	PRBS Bits Received	PRBS Errored Bits	PRBS BER	
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

Figure 1: Packet Group Statistic View

PRBS-related port statistics are shown in Figure 2 below in the blue fill-highlighted area:

- PRBS Frames Received
- Rx PRBS Frames with Header Error
- PRBS Bits Received
- PRBS Errored Bits
- PRBS Bit Error Rate (BER)



```
Card 06 - 10/100/1000 TXS4
    Port 01 - 10/100/1000 Base T
        Packet Streams
        Statistic View
        Management Interface
            MII Internal
    Port 02 - 10/100/1000 Base T
    Port 03 - 10/100/1000 Base T
    Port 04 - 10/100/1000 Base T
Card 07 - 10/100/1000 TX4
Card 08 - 1000 SFPS4
Card 09 - 1000 SFP4
Card 10 - 10/100 TXS8
Card 11 - 10/100/1000 XMS12
Card 12 - 10/100/1000 XMSR12
Card 13 - 10/100/1000 LSM XMV16
Card 14 - 10/100/1000 LSM XMVR16
Card 15 - Copper 10/100/1000
```

Sequence Frames	0	0
Sequence Errors	0	0
Protocol Server Vlan Dropped Frames	0	
Scheduled Frames Sent	0	0
Asynchronous Frames Sent	0	0
Port CPU Frames Sent	0	0
Scheduled Transmit Duration	0 : 0: 0.0	
Bytes Sent / Transmit Duration	0	
Bits Sent	0	0
Bits Received	0	0
Port CPU Status	Not Present	
Port CPU DoD Status	Not Ready	
PRBS Frames Received	0	0
Rx PRBS Frames with Header Error	0	0
PRBS Bits Received	0	0
PRBS Errored Bits	0	0
PRBS BER	0.000000e...	

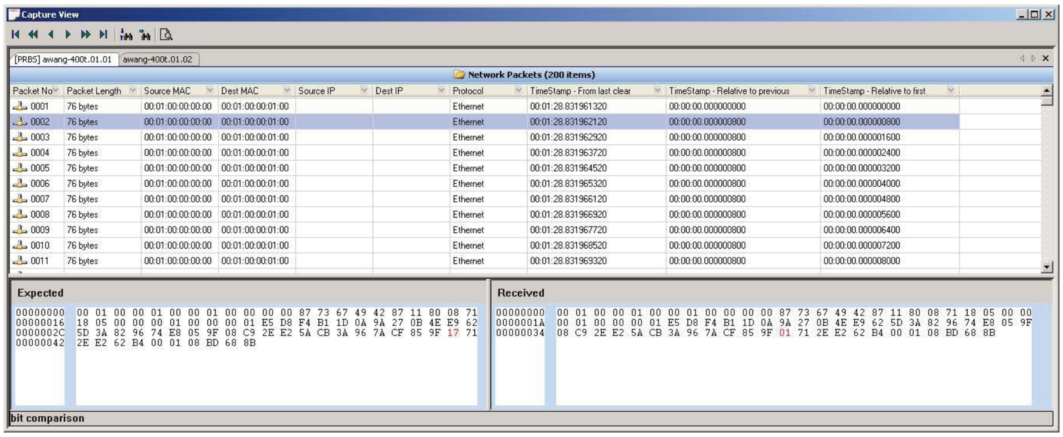
Figure 2: PRBS-related port statistics

In addition to PRBS statistics, IxExplorer offers a capture view specifically for PRBS analysis:

- Expected bit pattern
- Received bit pattern
- Actual errored bits
- Comparison views

The capture view window has two variations, one for standard capture view and one for PRBS capture mode. When PRBS mode is selected for both the transmit ports and the receive ports, the capture view dialog is configured as shown below. There is no packet tree view as in the standard capture view. In this example, an LM1000TXS4 card has been configured in a loopback fashion to transmit and receive packet streams in PRBS mode.

The Capture View Dialog for the PRBS Version is shown below in Figure 3:



Packet No	Packet Length	Source MAC	Dest MAC	Source IP	Dest IP	Protocol	TimeStamp - From last clear	TimeStamp - Relative to previous	TimeStamp - Relative to first
0001	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831961320	00:00:00.000000000	00:00:00.000000000
0002	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831962120	00:00:00.000000800	00:00:00.000000800
0003	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831962920	00:00:00.000000800	00:00:00.000001600
0004	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831963720	00:00:00.000000800	00:00:00.000002400
0005	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831964520	00:00:00.000000800	00:00:00.000003200
0006	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831965320	00:00:00.000000800	00:00:00.000004000
0007	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831966120	00:00:00.000000800	00:00:00.000004800
0008	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831966920	00:00:00.000000800	00:00:00.000005600
0009	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831967720	00:00:00.000000800	00:00:00.000006400
0010	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831968520	00:00:00.000000800	00:00:00.000007200
0011	76 bytes	00:01:00:00:00:00	00:01:00:00:01:00			Ethernet	00:01:28.831969320	00:00:00.000000800	00:00:00.000008000

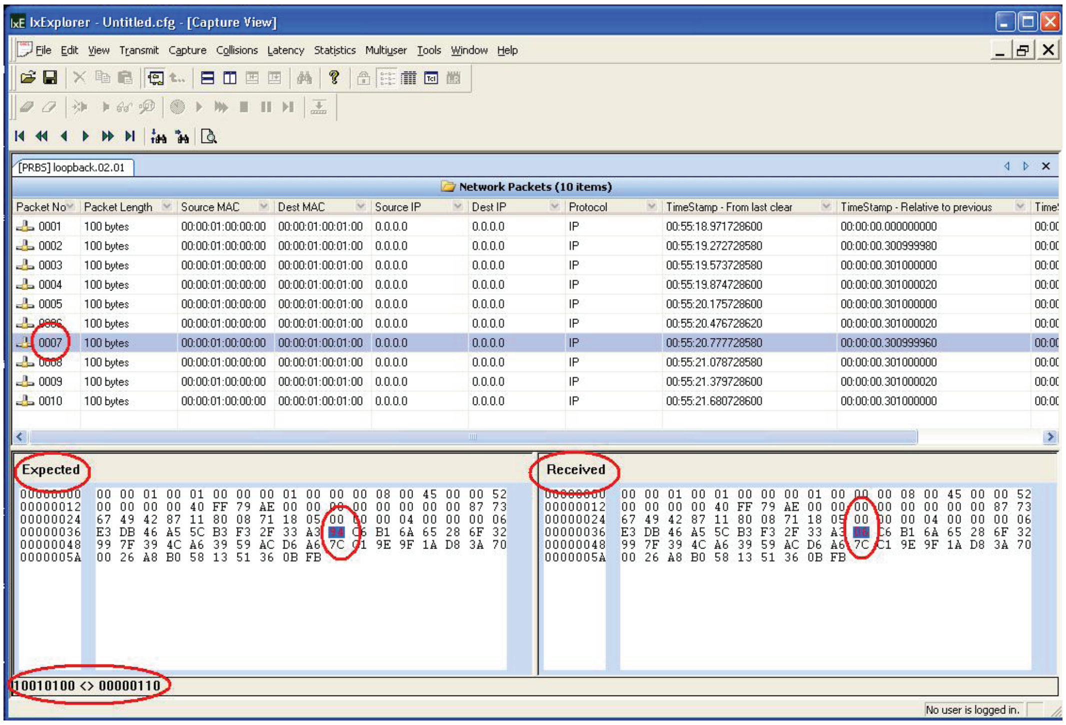
Expected

```
00000000  00 01 00 00 01 00 00 01 00 00 00 00 87 73 67 49 42 87 11 80 08 71
00000016  18 05 00 00 00 01 00 00 00 01 E5 D8 F4 B1 1D 0A 9A 27 0B 4E E9 62
0000002C  5D 3A 82 96 74 E8 05 9F 08 C9 2E E2 5A CB 3A 96 7A CF 85 9F 17 71
00000042  2E E2 62 B4 00 01 08 BD 68 8B
```

Received

```
00000000  00 01 00 00 01 00 00 01 00 00 00 00 87 73 67 49 42 87 11 80 08 71 18 05 00 00
0000001A  00 01 00 00 00 01 E5 D8 F4 B1 1D 0A 9A 27 0B 4E E9 62 5D 3A 82 96 74 E8 05 9F
00000034  08 C9 2E E2 5A CB 3A 96 7A CF 85 9F 01 71 2E E2 62 B4 00 01 08 BD 68 8B
```

bit comparison


IxExplorer - Untitled.cfg - [Capture View]
File Edit View Transmit Capture Collisions Latency Statistics Multiuser Tools Window Help
[PRBS] loopback.02.01
Network Packets (10 items)

Packet No	Packet Length	Source MAC	Dest MAC	Source IP	Dest IP	Protocol	TimeStamp - From last clear	TimeStamp - Relative to previous	Time
0001	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:18.971728600	00:00:00.000000000	00:0
0002	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:19.272728580	00:00:00.300999980	00:0
0003	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:19.573728580	00:00:00.301000000	00:0
0004	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:19.874728600	00:00:00.301000020	00:0
0005	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:20.175728600	00:00:00.301000000	00:0
0006	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:20.476728620	00:00:00.301000020	00:0
0007	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:20.777728580	00:00:00.300999960	00:0
0008	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:21.078728580	00:00:00.301000000	00:0
0009	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:21.379728600	00:00:00.301000020	00:0
0010	100 bytes	00:00:01:00:00:00	00:00:01:00:01:00	0.0.0.0	0.0.0.0	IP	00:55:21.680728600	00:00:00.301000000	00:0

Expected

```
00000000  00 00 01 00 01 00 00 00 01 00 00 00 08 00 45 00 00 52
00000012  00 00 00 00 40 FF 79 AE 00 00 00 00 00 00 00 00 87 73
00000024  67 49 42 87 11 80 08 71 18 05 00 00 00 04 00 00 00 06
00000036  E3 DB 46 A5 5C B3 F3 2F 33 A3 94 C6 B1 6A 65 28 6F 32
00000048  99 7F 39 4C A6 39 59 AC D6 A6 7C C1 9E 9F 1A D8 3A 70
0000005A  00 26 A8 B0 58 13 51 36 0B FB
```

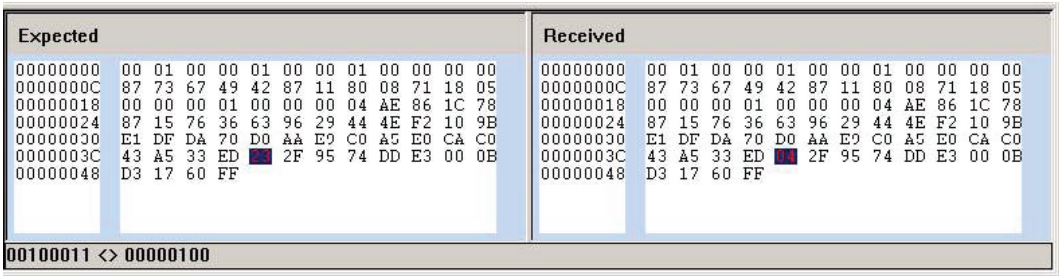
Received

```
00000000  00 00 01 00 01 00 00 00 01 00 00 00 08 00 45 00 00 52
00000012  00 00 00 00 40 FF 79 AE 00 00 00 00 00 00 00 00 87 73
00000024  67 49 42 87 11 80 08 71 18 05 00 00 00 04 00 00 00 06
00000036  E3 DB 46 A5 5C B3 F3 2F 33 A3 06 C6 B1 6A 65 28 6F 32
00000048  99 7F 39 4C A6 39 59 AC D6 A6 7C C1 9E 9F 1A D8 3A 70
0000005A  00 26 A8 B0 58 13 51 36 0B FB
```

```
10010100 <> 00000110
```

Figure 3: Capture View Dialog for PRBS

In the data view (lower) panel, the expected packet configuration is displayed on the left, and the received packet on the right. This enables a bit for bit comparison. Differences are highlighted in red. Select any byte in the data view, and a bit comparison will be revealed on the bottom frame.


Expected

```
00000000  00 01 00 00 01 00 00 01 00 00 00 00
0000000C  87 73 67 49 42 87 11 80 08 71 18 05
00000018  00 00 00 01 00 00 00 04 AE 86 1C 78
00000024  87 15 76 36 63 96 29 44 4E F2 10 9B
00000030  E1 DF DA 70 D0 AA E9 C0 A5 E0 CA C0
0000003C  43 A5 33 ED 23 2F 95 74 DD E3 00 0B
00000048  D3 17 60 FF
```

Received

```
00000000  00 01 00 00 01 00 00 01 00 00 00 00
0000000C  87 73 67 49 42 87 11 80 08 71 18 05
00000018  00 00 00 01 00 00 00 04 AE 86 1C 78
00000024  87 15 76 36 63 96 29 44 4E F2 10 9B
00000030  E1 DF DA 70 D0 AA E9 C0 A5 E0 CA C0
0000003C  43 A5 33 ED 04 2F 95 74 DD E3 00 0B
00000048  D3 17 60 FF
```

```
00100011 <> 00000100
```

Figure 4: Closer look at Capture View Dialog

PRBS Mode Frame Operation

The PRBS mode is different for the assembly, transmission, reception, detection, and error tracking of Ixia test traffic sent and received from a device under test (DUT).

In order to put PRBS mode frame handling into context, excerpts from the Ixia Hardware and Reference Manual (version 5.30) are shown here to explain the differences in PRBS mode.

In the standard traffic packet view transmit and receive mode, where both per-port and per-flow statistics may be enabled, several operations are active:

- Auto instrumentation
- Packet group operation
- Sequence checking
- Data integrity checking
- Wide packet groups

Automatic Instrumentation Signature

The automatic instrumentation signature feature allows the receive port to look for a signature at a variable offset from the start of frames. The feature supports sequence checking, latency, data integrity functionality, with signature and packet group IDs (when automatic instrumentation is enabled, these receive port options are enabled as well).

In normal stream operation, signatures for data integrity, latency, and sequence checking are forced to a single, uniform offset location in each frame of the stream. Many of the Ixia software application (for example, IxExplorer) can generate streams that place a signature at random places within the frames of a single stream. In order to accurately detect these signatures on the receive side of the chassis, automatic instrumentation signature is used.

Automatic instrumentation signature allows the chassis to look for a floating pattern in the frame. Two data blocks are placed in the frame by a stream generating application. The first is positioned at a variable offset from the start of the frame. The second is positioned at a fixed 12-byte offset from the end of the frame.

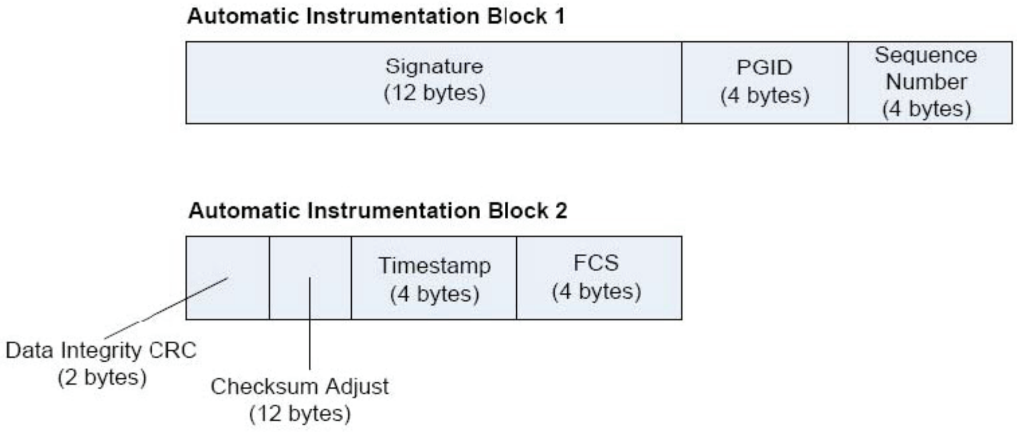

Automatic Instrumentation Block 1
Signature (12 bytes)
PGID (4 bytes)
Sequence Number (4 bytes)
Automatic Instrumentation Block 2
Timestamp (4 bytes)
FCS (4 bytes)
Data Integrity CRC (2 bytes)
Checksum Adjust (12 bytes)

Figure 5: Automatic Instrumentation Signature Block

The receive port recognizes an instrumented frame by detecting the signature in the first block. Once a signature match has occurred, the PGID and sequence number are extracted from the frame. Data integrity also starts immediately following the signature. The checksum adjust field is reserved for load modules that cannot correctly do checksums on large frames.

Packet Group Operation

Packet groups are sets of packets which have matching tags, called PGIDs. Real-time latency measurements within packet groups depend on coordination between port transmission and port reception. Each transmitted packet must include an inserted 4-byte packet group signature field, which triggers the receiving port to look for the PGID. This allows the received data to be recognized and categorized into packet groups for latency analysis.

PGIDs should be used to group similar packets. For example, packet groups can be used to tag packets connected to individual router ports. Alternatively, packet groups may be used to tag frame sizes. Such groupings allow the user to measure the latency with respect to different characteristics (for example, router port number or frame size as in the above scenario).

After packet group operation is triggered on the receiving port, the PGID — a 2-byte field which immediately follows the signature — is used as an index by the port’s receive buffer to store information related to the latency of the packet. When packet group signatures and PGIDs are included in transmitted data, an additional time stamp is automatically inserted into the packet. Figure 6 shows the fields within packets that are important for packet grouping and latency analysis.

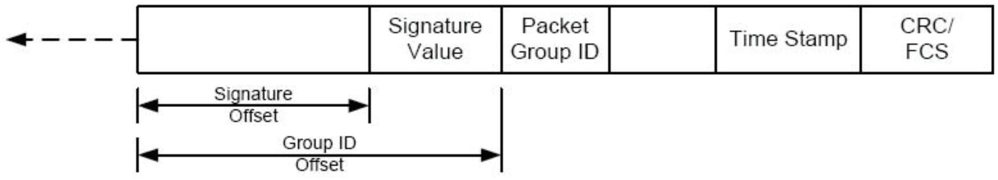


Figure 6: Packet Format for Packet Groups / Latency

A special version of packet groups, known as wide packet groups, uses a 4-byte PGID, of which only the low order 17 bits are active. A mask may be applied to the matching of the PGID. Latency, sequence checking, and first/last timestamps are supported at the same time. Latency over time and data integrity checking are not supported in this mode. Frames must be greater than or equal to 64 bytes.

Sequence Checking Operation

A number of ports have the additional ability to insert a sequence number at a user-specified position in each transmitted packet. This sequence number is different and distinct from any IP sequence number within an IP header. On the receiving port, this special sequence number is retrieved and checked, and any out-of-sequence ordering is counted as a sequence error.

As in packet groups, for sequence checking a signature value is inserted into the packet on the transmit side to signal the receive side to check the packet. In fact, this particular signature value is shared by both the packet group and the sequence checking operations. Both the signature value and sequence number are 4-byte quantities and must start on 4-byte boundaries. These fields are shown in Figure 7.

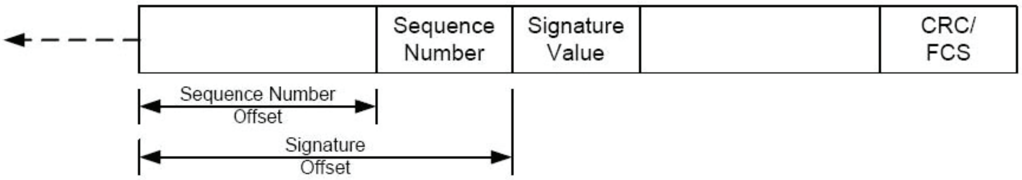


Figure 7: Packet Format for Sequence Checking

Sequence numbers are integers that start at "0" for each port when transmission is started, and increment by "1" continuously until a reset sequence index operation is performed. Note that multiple sequence errors will result when a packet is received out of sequence. For example, if five packets are transmitted in the order 1-2-3-4-5 and received in the order 1-3-2-4-5, three sequence errors will be counted:

- At 1-3, when packet 2 is missed
- At 1-3-2, when 2 is received after 3
- At 1-3-2-4, when 4 is received after 2

Data Integrity Checking Operation

A number of ports also possess the ability to check the integrity of data contained in a received packet, by computing an additional 16-bit CRC checksum. As with packet groups and sequence checking, a signature value is inserted into the packet on the transmitting interface to serve as a trigger for the receiving port to notice and process the additional checksum. The data integrity operation uses a different signature value from the one shared by packet groups and sequence checking.

The data integrity signature value marks the beginning of the range of packet data over which the 16-bit data integrity checksum is calculated, as shown in Figure 8. This packet data ends just before the timestamp and normal CRC/FCS. The CRC-16 checksum value must end on a 4-byte boundary. There may be 1, 2, or 3 bytes of zeroes (padding) inserted after the CRC-16, but before the Time Stamp, to enforce all boundary conditions.

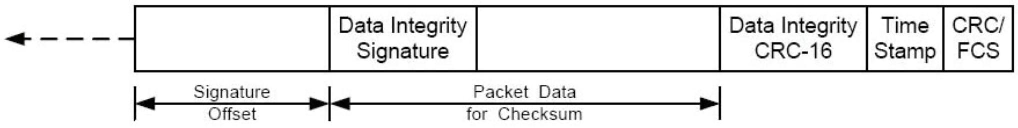


Figure 8: Packet Format for Data Integrity Checking

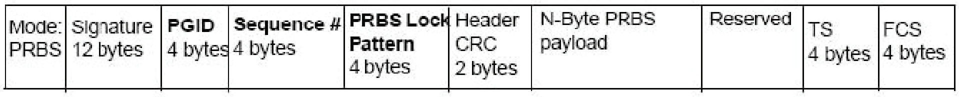
When the receive code for a port is configured to check for data integrity, received packets are matched for the data integrity signature value, and the additional CRC-16 is checked for accuracy. Any mismatches are recorded as data integrity errors.

Wide Packet Groups

This feature allows ports that use packet groups to extend the number of bits in the PGID to 17 bits (or more).

When the receive mode is set to PRBS mode, both wide packet groups and sequence checking are automatically enabled. Latency is turned off and replaced by PRBS statistics, as described previously.

In PRBS mode, the auto instrumentation feature is automatically enabled for the transmit ports and the receive ports. In PRBS mode the Ixia test system is automatically set to provide per-flow (PGID) and per-port PRBS statistics. This is why Wide packet Groups and Sequence Checking via PGID modes are enabled. These modes must be enabled to also produce PRBS measurements. Other modes such as Data Integrity reporting must be turned off. The structure of a PRBS frame is shown below.



Mode: PRBS	Signature 12 bytes	**PGID** 4 bytes	**Sequence #** 4 bytes	**PRBS Lock Pattern** 4 bytes	Header CRC 2 bytes	N-Byte PRBS payload	Reserved	TS 4 bytes	FCS 4 bytes

Figure 9: Packet Format in PRBS Mode

PRBS mode has qualification modes for frames entering the receive port in a PRBS test:

- The signature must be matched from the transmit port,
- The frame CRC will be treated as a do not care, and
- The Header CRC will be treated as shown in the table below:

Header CRC	PRBS Error	Action
Good	None	Increase both PGID statistics (per-flow) and port-level statistics (per-port), and do not pass to PRBS capture
Good	Error	Increase both PGID statistics and port-level statistics, and pass to the PRBS capture
Bad	Do not care	Increase PRBS port-level statistics

For both per-port and per-flow statistics, the running frame count and the frame rates will be available to their respective statistical counters.

The table below shows the frame modifications required when in the PRBS mode versus the standard packet mode (i.e. Sequence).

The frame diagram shown below is a packet with auto instrumentation (shown from the auto instrumentation block offset to the end of the packet). The region in blue highlight shows the range over which the data integrity (DI) CRC value is calculated. Note, that for PRBS mode, the DI CRC only covers the packet header and not the actual payload. The payload when in PRBS mode must be a continuous PRBS pattern up to but not including the reserved block.*

Table 1: Auto Instrumentation Packet Format

Mode	12 Bytes	4 Bytes	4 Bytes	4 Bytes	2 Bytes	N-2 Bytes	2 Bytes	2 Bytes	4 Bytes	4 Bytes
PRBS	Signature	PGID	Sequence Number	PRBS Lock Pattern	DI CRC	N Bytes PRBS Payload		Reserved Block*	Time Stamp	FCS
Sequence Checking	Signature	PGID	Sequence Number	N Byte Payload			DI CRC	Reserved Block*	Time Stamp	FCS

Note, that the PRBS payload pattern (shown in black double-line outline blocks) is contiguous from the PRBS Lock Pattern through the end of the "N Byte PRBS Payload." The DI CRC is overlaid on top of the PRBS payload.

On the receive side, the PRBS checker must lock onto the PRBS Lock Pattern and then start checking from the start of the "N Byte PRBS payload" and skip the DI CRC. The DI CRC block is used to qualify the state (health) of the packet header, however, the DI CRC is not reported to the user as a data integrity check as described in the standard packet mode (i.e. sequence) when in the PRBS mode.

Ixia uses a polynomial and a seed mechanism that produces the "N Byte PRBS Payload." The transmit ports and the receive ports both know the output of the polynomial, which is what allows a comparison of the "N Byte PRBS Payload" between the transmitted packet and the received packet. The mechanisms that manage the PRBS generation and checking are proprietary to Ixia.

All of the offsets of the various fields shown in the figure above are fixed offset; if the DUT inserts or changes the offset or content of the frame block that are in the blue region, the PRBS system will report errors. Once the "N Byte PRBS Payload" is generated, if the DUT changes or pads the N Byte PRBS content, the Ixia receive side will see that as an error and will report PRBS Errored Bits on the receive port.

*Note. The reserved block is proprietary to Ixia.

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