



FEC Analysis MU196040B-x42

PAM4 ED MU196040B

Signal Quality Analyzer-R
MP1900A Series



Data centers supporting next-generation, high-speed, large-capacity 5G mobile communications are progressing with introduction of equipment meeting the 400 GbE communications standard, while also starting investigation of 800 GbE and 1.6 TbE standards to facilitate even faster speeds.

The PAM4 transmission method used by 400 GbE expresses digital data using four voltage levels per unit time to transmit twice as much data compared to the earlier conventional NRZ method. However, due to the narrower differences between the four voltage levels, the greater susceptibility to noise and transmission-path losses makes error-free transmission more difficult than using the conventional NRZ method. As a result, error correction using FEC is applied to assure transmission quality. Consequently, evaluation of devices and transceivers supporting PAM4 not only requires jitter tolerance and sensitivity evaluations based on conventional bit error and error-free measurements, but also requires measurement of error-correction capability using FEC.

Features of FEC Analysis Function

- Detects both bit errors and FEC Symbol Errors in real-time
- Measures jitter tolerance referenced to FEC Symbol Error count as a pass/fail criterion
- Displays distribution of FEC Symbol Errors per Codeword in real-time
- Supports input signal capture at timing exceeding FEC symbol threshold to debug burst errors

[Target Applications] 50, 100, 200, 400, and 800 GbE

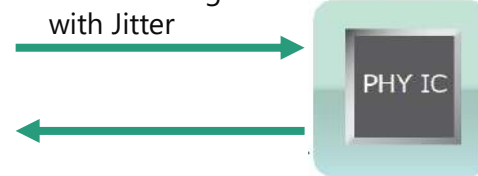
High-sensitivity 116-Gbit/s PAM4 ED supports reliable FEC Symbol Error measurements

MP1900A PAM4 BERT



PAM4 Test Signal with Jitter

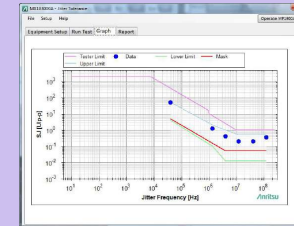
Test Board



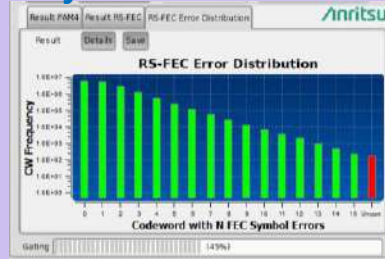
Real-time FEC Symbol Error Measurement

Result PAM4		Result RS-FEC		Bit		
	Uncorr. Codeword	FEC Symbol	Total	INS	OMI	
MSB	ER	2.192 300E-06	2.199 500E-07	4.382 900E-07	1.555 200E-09	
	EC	25 623	26 876	26 781	95	
LSB	ER	2.728 900E-03	2.758 500E-04	4.223 500E-04	1.293 100E-04	
	EC	3.189 400E+07	3.223 900E+07	2.468 300E+07	7 556 450	
MSB + LSB	ER	0.000 000E-00	1.365 500E-03	1.381 200E-04	2.116 100E-04	6.462 300E-05
	EC	0	3.192 000E+07	3.375 500E+07	2.586 000E+07	7 895 263

Jitter Tolerance Test Based on Correctable/Uncorrectable FEC



FEC Symbol Error Distribution



FEC Symbol Capture



Real-time FEC Symbol Error Measurement

Uncorrectable Codeword, FEC Symbol Error, and Bit Error measurement results on one screen

MSB/LSB Errors and Codeword Counts and Rate for each Symbol Error Count on Details Screen

MU196040B PAM4 ED Result Screen

Summary Table:

	Uncorr. Codeword	FEC Symbol	Bit
ER	5.120 000E-08	3.504 500E-03	1.804 400E-04
EC	1	1.861 800E+07	1.917 100E+07
%EFl	90.000 000	0.000 000	
EI	1	10	

Frequency(kHz): 53 124 999 Clock Count: 5.312 400E+10
Total Codeword Count: 1.953 100E+07

Summary Indicators:
 Clock Loss: 0
 Sync Loss: 0
 PAM4 Symbol/Bit Error: ● ●
 FEC Symbol Error(MSB): ● ●
 FEC Symbol Error(LSB): ● ●
 Uncorr. Codeword Error: ● ●

Table 1: Error Counts and Rates

		Uncorr. Codeword	FEC Symbol	Bit		
				Total	INS	OMI
MSB	ER	5.120 000E-08	6.934 500E-04	3.503 500E-05	6.975 900E-05	3.121 300E-07
	EC		1 841 995	1 861 282	1 852 991	8 291
LSB	ER	1	6.315 700E-03	3.258 400E-04	3.116 500E-04	3.400 300E-04
	EC		1.677 600E+07	1.731 000E+07	8 278 443	9 032 132
MSB + LSB	ER	1	3.504 500E-03	1.804 400E-04	1.907 000E-04	1.701 700E-04
	EC		1.861 800E+07	1.917 100E+07	1.013 100E+07	9 040 423

Table 2: FEC Symbol Error Count Summary

FEC Symbol Error Count	Codeword Rate	Codeword Count
0	4.330 700E-01	8 458 502
1	3.167 900E-01	6 187 331
2	1.582 500E-01	3 090 827
3	6.127 600E-02	1 196 814
4	2.105 900E-02	411 311
5	6.644 200E-03	129 771
6	2.030 000E-03	39 649
7	6.084 000E-04	11 883
8	1.843 700E-04	3 601
9	5.631 900E-05	1 100
10	1.607 600E-05	314
11	4.352 000E-06	85
12	2.048 000E-06	40
13	6.144 000E-07	12
14	3.584 000E-07	7
15	1.024 000E-07	2
Uncorr. Codeword	5.120 000E-08	1

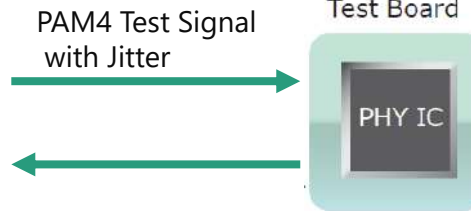
Summary Indicators:
 Clock Loss: 0
 Sync Loss: 0
 PAM4 Symbol/Bit Error: ● ●
 Uncorr. Codeword Error: ● ●
 FEC Symbol Error(MSB): ● ●
 FEC Symbol Error(LSB): ● ●

Jitter Tolerance Measurements Based on FEC Symbol Errors

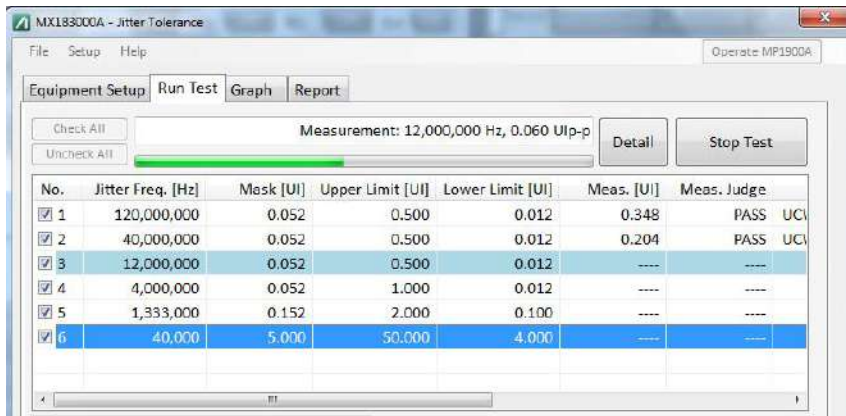
 [Sample Video](#)

One-button jitter tolerance measurement is supported based on whether or not error correction using FEC is possible.

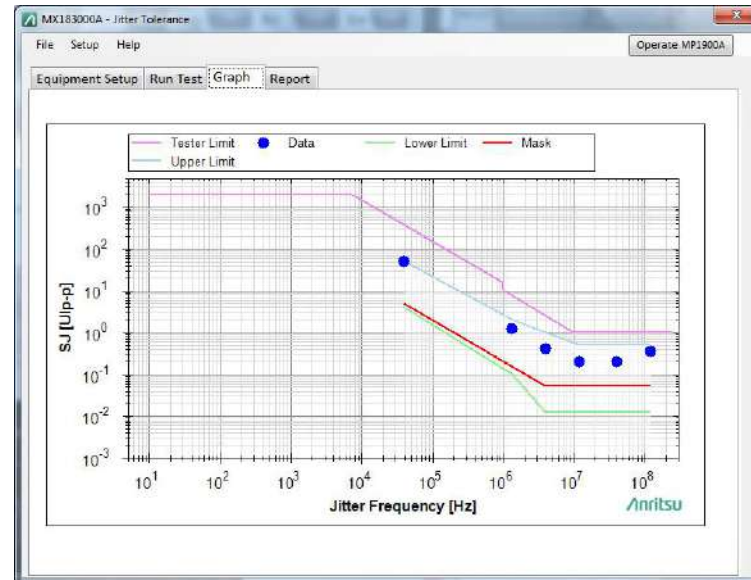
MP1900A PAM4 BERT



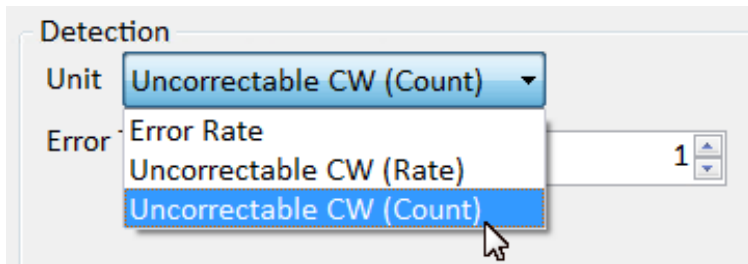
Jitter Frequency and Test Mask Settings



Correctable Error Jitter Tolerance Test Result



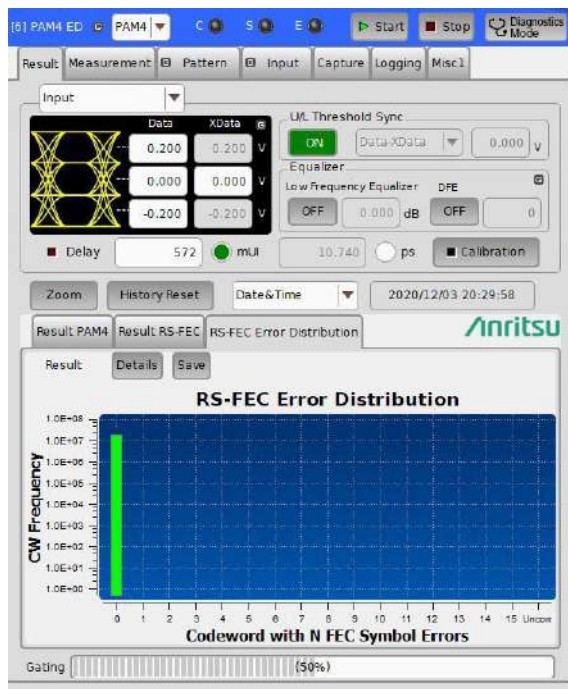
Test Criterion Setting, Bit Error or Uncorrectable Codeword



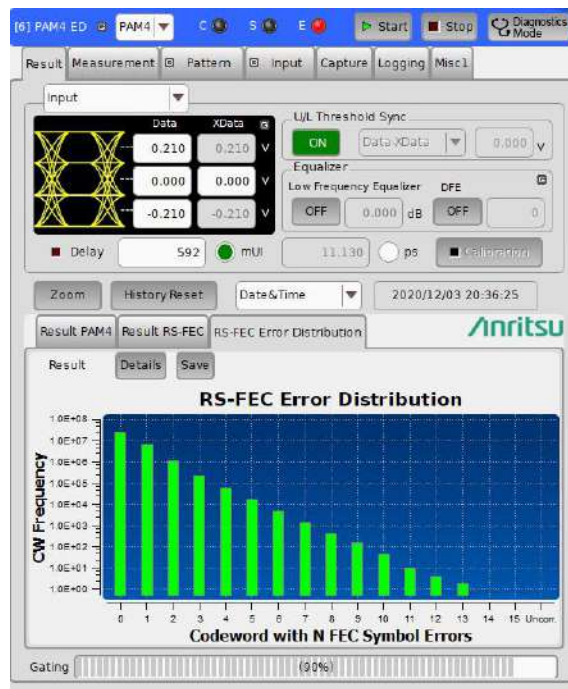
FEC Symbol Error Distribution in Real-time

[Sample Video](#)

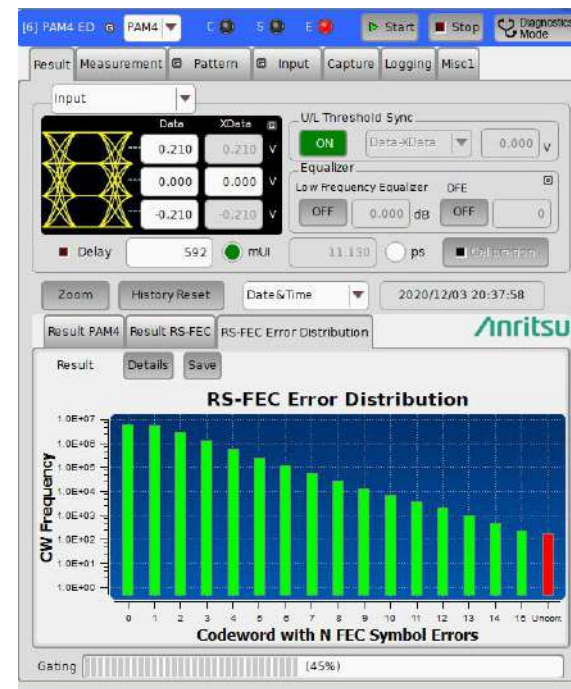
Error Free



Correctable Errors



Uncorrectable Errors

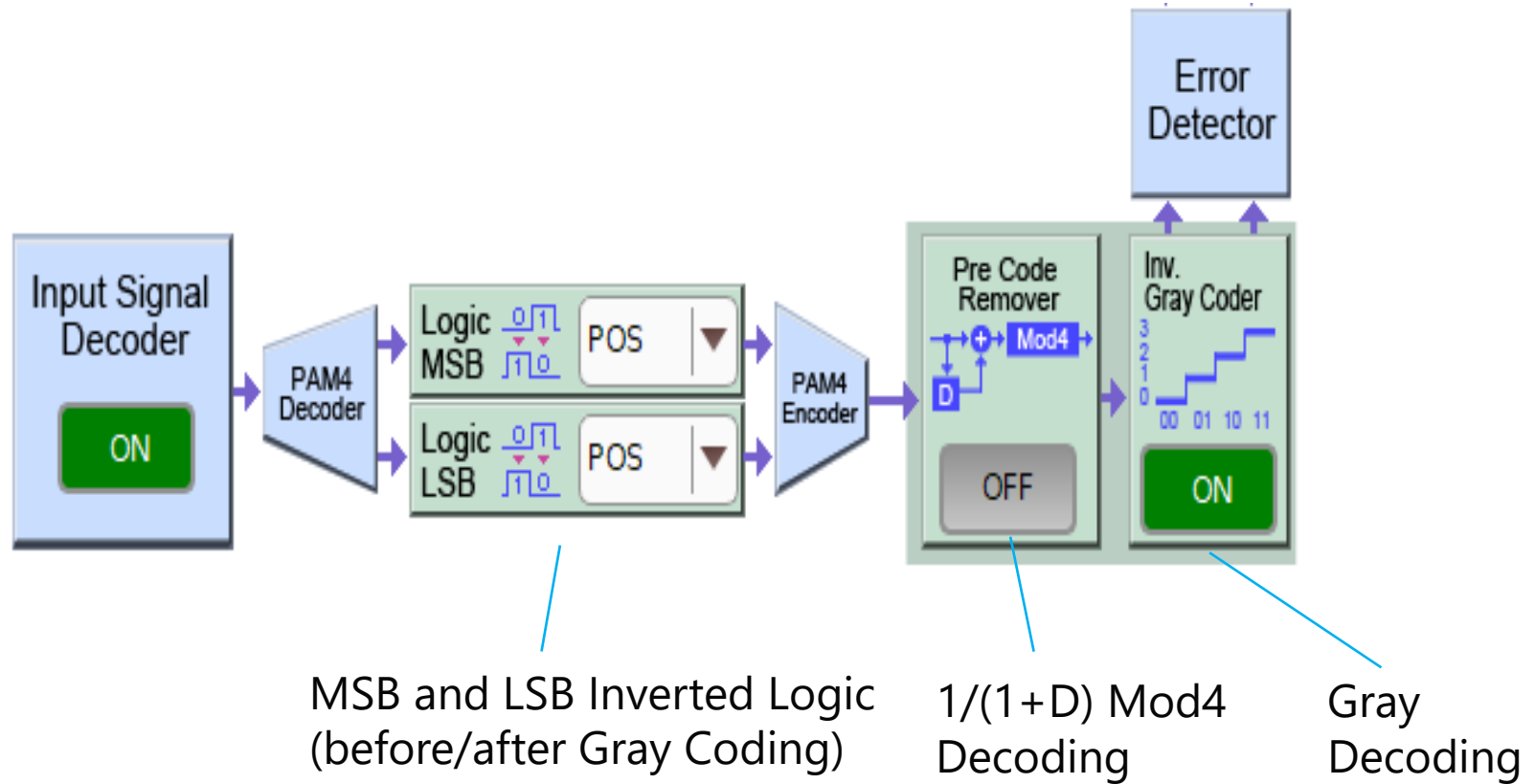


Stress Injection

Decoding Function

Supports Gray decode function

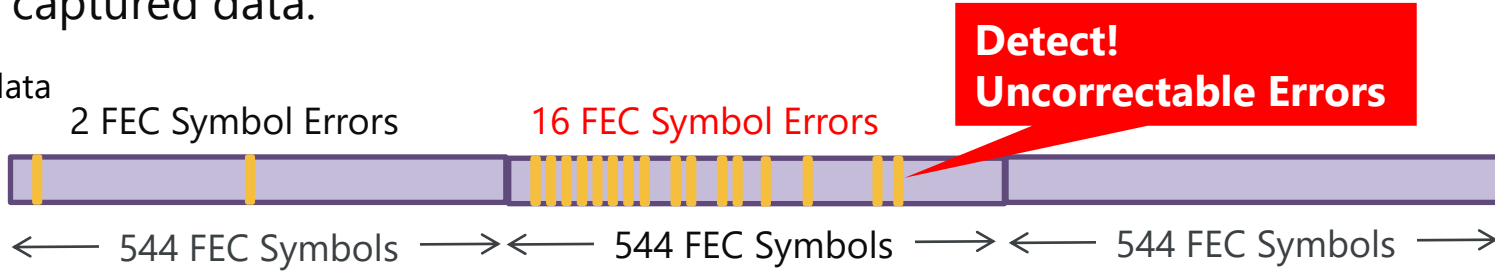
Decodes input data and measures FEC Symbol Errors



FEC Symbol Capture

The input data is captured when the number of FEC Symbol Errors exceeds the threshold setting. The causes of FEC-uncorrectable errors can be analyzed from the captured data.

Input data



Captured Data

Capture

File	LSB: 2097015	Cursor Addr 2097015	Position 2097015	Pattern Addr 1128719893	Block
	+0	+10	+20	+30	1
02096910 MSB	0 1 0 0 1 1 1 1 0 0	1 1 1 0 1 1 1 1 0 1	1 1 1 0 1 1 1 0 1 1		
02096910 LSB	0 1 0 1 0 0 1 0 1 1	0 0 0 1 0 0 1 1 0 0	1 0 0 0 1 0 0 1 1 0		
02096940 MSB	1 1 1 0 0 1 0 0 0 1	0 0 1 1 0 1 0 1 1 0	1 0 1 1 0 0 1 1 0 1		
02096940 LSB	1 1 1 0 0 0 1 0 0 1	1 1 0 0 1 1 1 0 0 0	0 1 1 0 0 0 1 0 0 0		
02096970 MSB	1 0 0 1 1 1 1 1 1 0	0 0 1 1 0 0 1 1 1 0	0 1 1 0 1 0 1 1 1 1		
02096970 LSB	1 1 1 1 1 0 0 0 1 1	1 1 1 1 1 1 0 1 1 1	1 0 1 1 1 0 0 1 1 1		
02097000 MSB	0 1 0 0 1 1 1 0 0 0	0 0 1 0 1 0 0 0 0 1	0 1 1 0 0 1 0 1 0 1		
02097000 LSB	1 0 1 1 1 1 1 1 1 0	0 0 1 1 0 1 0 0 1 1	0 1 1 1 0 1 1 1 1 1		
02097030 MSB	1 1 1 0 0 0 0 0 1 1	1 1 0 0 1 0 1 1 1 0	1 1 1 1 1 1 0 0 0 0		
02097030 LSB	0 0 1 1 0 0 0 1 1 1	0 0 1 1 0 1 1 0 0 1	0 1 0 1 0 1 0 0 0 0		
02097060 MSB	1 1 0 0 1 1 1 0 1 1	1 1 1 1 0 0 0 0 0 1	1 1 1 1 1 0 1 1 0 0		
02097060 LSB	0 0 1 1 1 1 0 1 0 1	0 0 0 0 0 1 1 1 0 1 1	0 1 1 1 0 0 0 0 1 0		
02097090 MSB	1 0 1 0 1 0 1 0 1 1	1 0 0 0 0 1 1 0 0 0	1 1 0 0 1 0 1 0 1 1		
02097090 LSB	0 1 1 1 0 0 1 1 0 0	1 1 0 1 1 0 0 1 0 0	0 1 1 1 1 0 0 0 0 1		
02097120 MSB	0 0 0 0 0 0 1 1 0 0	0 0 1 0 0 1 0 0 0 0	1 0 1 1 0 0 0 1 1 0		
02097120 LSB	1 1 1 1 0 0 0 1 0 1	0 0 1 0 1 1 1 0 1 1	0 1 0 1 1 1 1 1 1 1		
02097150 MSB	0 1 1 1 1 0 1 1 0 1	0 1 1 1 1 1 0 1 0 1	0 1 1 0 0 0 0 1 0 1		
02097150 LSB	0 0 1 1 1 1 1 1 1 1	0 0 1 0 0 1 0 1 0 0	1 1 0 1 0 0 0 0 1 1		

Block Length: 4194300 symbol

Trigger Position: 2096896 symbol

Viewer Mode: Notation Bin(MSB/LSB) Format Pattern

Move and Search: Pattern Target All

Error Search: Continuous Error 1 bit Target All

	First Error Block/Address	Last Error Block/Address	Total Error Counts Bit Error/Total Bits	Total FEC Symbol Error Counts FEC Symbol Error/Total FEC Symbols	CaptureDepth
MSB	1 2097030	1 2097128	8 4194300	7 419430	4194300
LSB	1 2096954	1 2097136	27 4194300	16 419430	4194300

