Anritsu envision : ensure

PAM4 Signal Generation and BER Measurement Solution

Signal Quality Analyzer
MP1800A Series

Introduction

The recent spread of smartphones and cloud computing applications is driving exponential growth in traffic at data centers. To transfer these large data volumes at high speed, Ethernet communications standards are progressing with deployment of 100GbE equipment, and 400GbE is already being targeted for next-generation standards.

Transmission technologies for implementing high-speed, large-volume transfers are centered on PAM (Pulse Amplitude Modulation) methods offering both faster symbol rates than earlier NRZ signal methods as well as increased transmission capacity without increased symbol rates.

This presentation introduces the MP1800A Signal Quality Analyzer as a measurement solution supporting next-generation transmission standards, such as 200GbE and 400GbE.

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Standards for High-Speed Interconnects using PAM4

Optical Interface

	Standard	Distance	Format	Baud Rate
400G	400G BASE-SR16	100 m	NRZ	26.6G
	400G BASE-DR4	**500 m**	**PAM4**	**53.1G**
	400G BASE-FR8	**2 km**	**PAM4**	**26.6G**
	400G BASE-LR8	**10 km**	**PAM4**	**26.6G**
200G	**200G BASE-SR4**	**100 m**	**PAM4**	**26.6G**
	200G BASE-DR4	**500 m**	**PAM4**	**26.6G**
	200G BASE-FR4	**2 km**	**PAM4**	**26.6G**
	200G BASE-LR4	**10 km**	**PAM4**	**26.6G**
100G	100G BASE-SR10	100/150 m	NRZ	10.3G
	100G BASE-SR2	**100 m**	**PAM4**	**26.6G**
	100G BASE-DR	**500m**	**PAM4**	**53.1G**
	100G BASE-SR4	70/100 m	NRZ	25.8G
	100G SWDM	400 m	NRZ	25.8G
	100G PSM4	500 m	NRZ	25.8G
	CWDM4/CLR4	2 km	NRZ	25.8G
	100G BASE-LR4	10 km	NRZ	25.8G
	100G BASE-ER4	40 km	NRZ	25.8G
50G	**50G BASE-SR**	**100 m**	**PAM4**	**26.6G**
	50G BASE-FR	**2 km**	**PAM4**	**26.6G**
	50G BASE-LR	**10 km**	**PAM4**	**26.6G**
25G	25G BASE-SR	100 m	NRZ	25.8G
	25G BASE-FR	2 km	NRZ	25.8G
	25G BASE-LR	10 km	NRZ	25.8G

Electrical Interface

	Standard IEE802.3bs	Format	Baud Rate
400G	400GAUI-16	NRZ	26.6G
	400GAUI-8	**PAM4**	**26.6G**
200G	200GAUI-8	NRZ	26.6G
	200GAUI-4	**PAM4**	**26.6G**
100G	CAUI-10	NRZ	10.3G
	CAUI-4	NRZ	25.8G
50G	**50GAUI**	**PAM4**	**26.6G**
25G	25GAUI	NRZ	25.8G

	Standard IEE802.3cd	Format	Baud Rate
200G	**200G BASE-CR4**	**PAM4**	**26.6G**
	200G BASE-KR4	**PAM4**	**26.6G**
100G	100G BASE-CR4	NRZ	25.8G
	100G BASE-KR4	NRZ	25.8G
	100G BASE-KP4	**PAM4**	**13.6G**
	100G BASE-CR2	**PAM4**	**26.6G**
	100G BASE-KR2	**PAM4**	**26.6G**
50G	**50G BASE-CR**	**PAM4**	**26.6G**
	50G BASE-KR	**PAM4**	**26.6G**

Example of PAM4 Signal Applications (1)

- 26.5625 Gbaud 400GAUI-8 Electrical and 400GBASE-FR8, LR8 Optical Interfaces

26.5625 Gbaud x 8 PAM4 Electrical Interface

26.5625 Gbaud x 8 PAM4 Optical Interface

400GAUI-8 (PAM4)

Line Card

CFP8

BUS

Interface

ASIC/ 50G SERDES

x8

Re-timer IC

x8

Driver

x8

LD

x8

WDM MUX

TIA

PD

WDM DEMUX

Optical Interface

Test Point

	400GAUI-8 Electrical Interface	Driver Output, LD Input Electrical Interface	400GBASE-FR8, LR8 Optical Interface
Baud Rate	26.5625 Gbaud (53.125 Gbit/s)/Lane		
Lane Number	8		1 Single-mode Fiber (1310-nm Wavelength)
Main Measurement Items	・BER Test ・Eye Mask (EH, EW, Linearity) ・Tx/Rx Equalizer Function ・Jitter Addition Test (RJ/SJ/DCD) ・Crosstalk Test	・Eye Mask (EH, EW, Linearity) ・I/O Power Characteristics	・Average Optical Power ・OMA (Optical Modulation Amplitude) ・TDECQ(Transmitter and Dispersion Eye Closure for PAM4) ・Extinction Ratio ・Optical Stress Test

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Example of PAM4 Signal Applications (2)

- 53.125 Gbaud 4-lane Electrical and 400GBASE-DR4 Optical Interfaces

53.125 Gbaud x 4 PAM4 Electrical Interface

53.125 Gbaud x 4 PAM4 Optical Interface

400GAUI-8 (PAM4)

Line Card

BUS

Interface

ASIC/ 50G SERDES — x8 — PAM4 Transceiver IC — x4 — Driver — x4 — LD — x4 → Optical Interface

TIA ← PD

Test Point
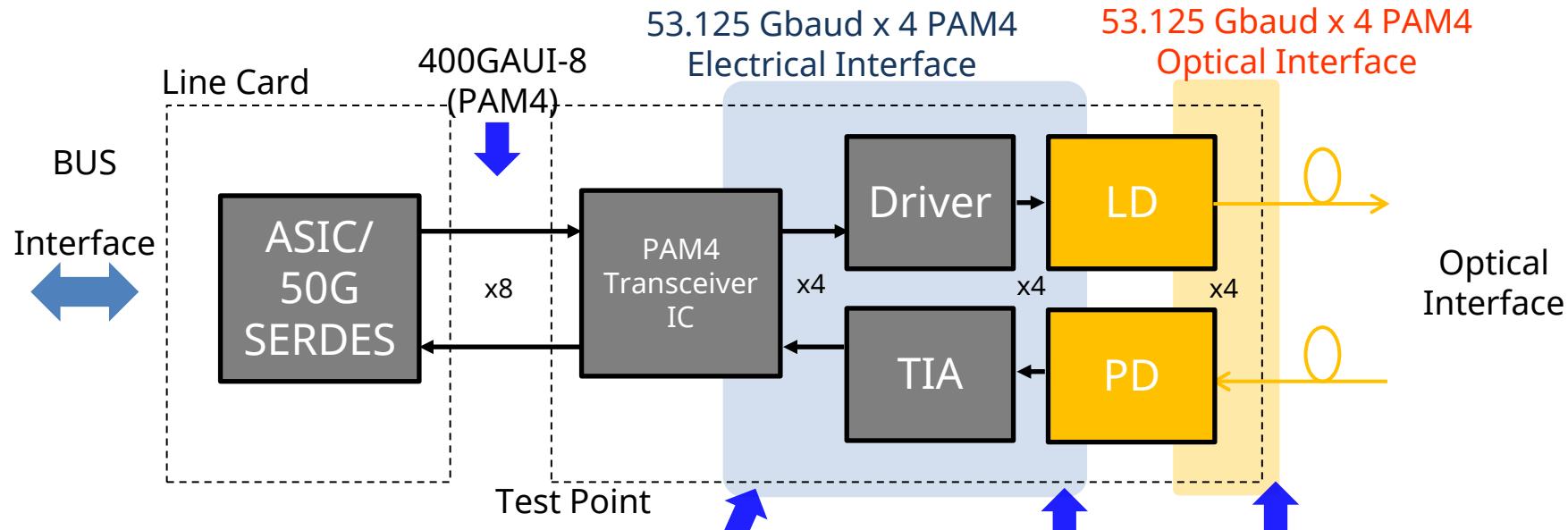
	53 Gbaud 4-lane Electrical Interface	Driver Output, LD Input Electrical Interface	400GBASE-FR8,LR8 Optical Interface
Baud Rate	53.125 Gbaud (106.25 Gbit/s)/Lane		
Lane Number	4		4-lane Single-mode Fiber (1310-nm Wavelength Band)
Main Measurement Items	・BER Test ・Eye Mask (EH, EW, Linearity) ・Tx/Rx Equalizer Function ・Jitter Addition Test (RJ/SJ/DCD) ・Crosstalk Test	・Eye Mask (EH, EW, Linearity) ・I/O Power Characteristics	・Average Optical Power ・OMA (Optical Modulation Amplitude) ・TDECQ(Transmitter and Dispersion Eye Closure for PAM4) ・Extinction Ratio ・Optical Stress Test

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Features of MP1800A Series PAM4 Measurement Solution

- Supports high 64 Gbaud rate both PAM4 and NRZ
- 32 Gbaud 4ch PAM4 transmissions (256 Gbit/s/one MP1800A)
- Excellent expandability
  - 32 Gbaud 4ch multi-channel
    Expandable from 32 Gbaud to 64 Gbaud
- Low Intrinsic Jitter and high-quality waveform output
- High amplitude PAM4 output (G0375A + 32G PPG)
- High-input sensitivity BER detection
- Supports 28 Gbaud CTLE and CDR functions (G0376A +32G ED)
- Supports receiver Jitter tolerance tests

Future-proof instrument configuration

Efficient inspection supported by functions and performance

[PAM4 Applications]
- 28 Gbaud PAM4 ICs, backplanes, active optical cables, CEI-56G-PAM4
- 53 Gbaud/26 Gbaud 200GbE/400GbE optical modules, optical devices, ICs

NRZ/Multichannel Solution
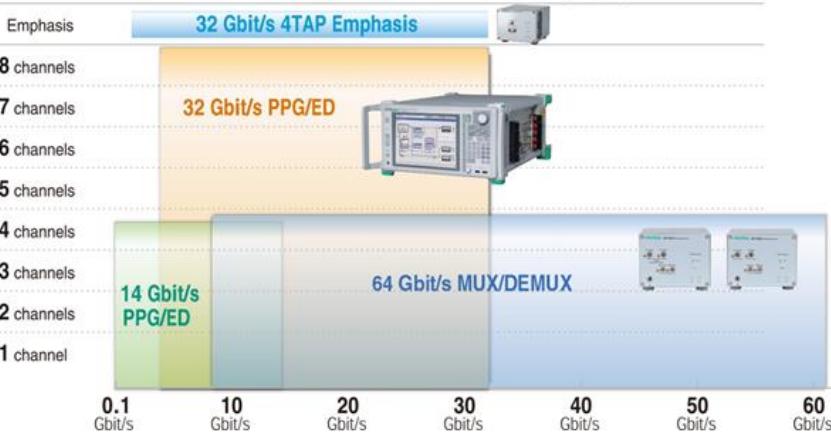
PAM4/Multichannel Solution
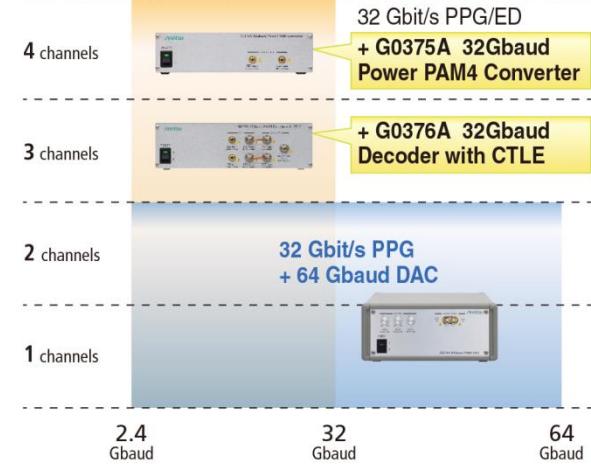
Recommended PAM4 BER Measuring Instruments (1)

32 Gbaud Standard Configuration

Model	Name	Option	Qty	Remark
MP1800A	Signal Quality Analyzer	001, 002, 007, 015, 032	1	
MU181000B	12.5 GHz 4 port Synthesizer	-	1	
MU181500B	Jitter Generation Source	-	1	For Jitter Tolerance Test
MU183020A	28G/32Gbit/s 2ch PPG	023, 031	1	Two units for PAM4 Linearity control
G0375A MZ1834A/B MZ1838A	32Gbaud Power PAM4 Converter 4PAM Converter 8PAM Converter	-	1	Select one using output amplitude function
MU183040B	28G/32Gbit/s High Sensitivity ED	010 Or 020, 022	1	010: At 1ch 3 Eye sequential BER measurement 020, 022: At total BER measurement as set with G0376A
G0376A	32Gbaud PAM4 Decoder with CTLE	-	1	At total BER measurement as set with MU183040B-020, 022

Anritsu envision : ensure

Recommended PAM4 BER Measuring Instruments (2)

64 Gbaud Standard Configuration

Model	Name	Option	Qty	Remark
MP1800A	Signal Quality Analyzer	001, 002, 007, 015, 032	1	
MU181000B	12.5 GHz 4 port Synthesizer	-	1	
MU181500B	Jitter Generation Source	-	1	For Jitter Tolerance Test
MU183020A	28G/32Gbit/s PPG	022, 031	2	Also possible with Option 023
MU183040B	28G/32Gbit/s High Sensitivity ED	020	1	
G0374A	64Gbaud PAM4 DAC	-	1	
MP1862A	56G/64Gbit/s DEMUX	-	1	

Anritsu envision : ensure

PAM4 Signal Generation (1)

- Low Intrinsic Jitter and high-quality waveform output support efficient verification
- Expandability for measurement application and baud rate
- High-amplitude PAM4 output (G0375A) for direct-driving optical modulator without external amplifier

	32 Gbaud Signal Generation **PAM4 Converter MZ18xx/G0375A** **+ MU18302xA PPG**	64 Gbaud Signal Generation **G0374A/G0361A** **+ MU18302xA PPG (4ch)**
Baud Rate	2.4 to 32.1 Gbaud (4.8 to 64.2 Gbit/s)	4.8 to 64 Gbaud (9.6 to 128 Gbit/s)
Tr/Tf (20% to 80%)	12 ps (typ.)	8 ps (typical)
Amplitude (Single-End)	・**MZ1834A** + 2ch PPG 0.238 to 0.475 V (w/ 2V option PPG) 0.238 to 0.832 V (w/ 3.5V option PPG) ・**MZ1834B** + 2ch PPG 0.376 to 0.753 V (w/ 2V option PPG) 0.376 to 1.318 V (w/ 3.5V option PPG) ・**MZ1838A** + 3ch PPG (3Eye independently variable level) 0.119 to 0.378 V (w/ 2V option PPG) 0.119 to 0.662 V (w/ 3.5V option PPG) **High-amplitude support** (Baud rate of 10 to 32.1G) ・**G0375A** + 2ch or 3ch PPG 1.5 to 2.2 V	0.7 V (typ.) >6 dB controllable

Anritsu envision : ensure

PAM4 Signal Generation (2)

・32-Gbaud PAM4 Signal Generation 1
(3 Eye equivalent or symmetrical variable level)

MP1800A
2ch PPG

NRZ Data CH1

NRZ Data CH2

MZ1834A/B
4PAM Converter

Differential 4PAM Signal

・32-Gbaud PAM4 Signal Generation 2
 (Supports evaluations of LDs and optical devices using 3 Eye independently variable level)

MP1800A
2ch PPG

NRZ Data CH1

NRZ Data CH2

NRZ Data CH3

MZ1838A
8PAM Converter

Differential 4PAM Signal

Anritsu envision : ensure
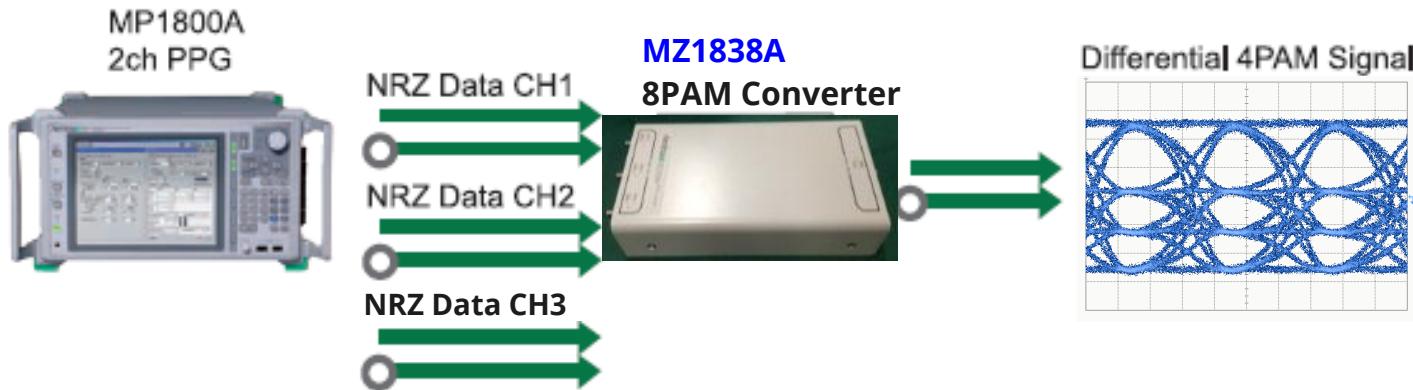
PAM4 Signal Generation (3)

・32-Gbaud High-amplitude PAM4 Signal Generation
  High-amplitude PAM4 Signal Output 2.2 Vp-p (Single-end), 4.4 Vp-p (Differential)
  Clean Eye and Low Jitter
  Compact Remote Head
  Emphasis Output (set with MP1825B)

(*) CH3 used for PAM4 Linearity control

PAM4 Signal Generation (4)

➤ Typical MZ1834A/B waveforms

Supports accurate Eye Margin and high-reproducibility measurements using high-quality output waveforms with low Intrinsic Jitter

- **MZ1834A**

28 Gbaud, 0.832 V
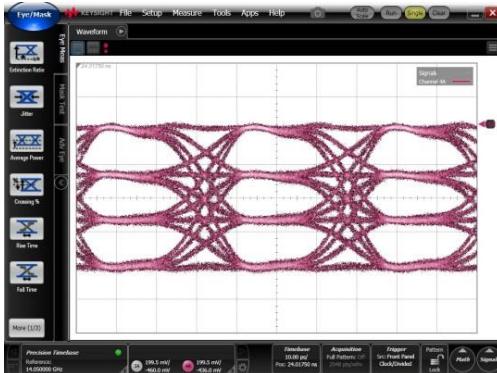
32.1 Gbaud, 0.832 V
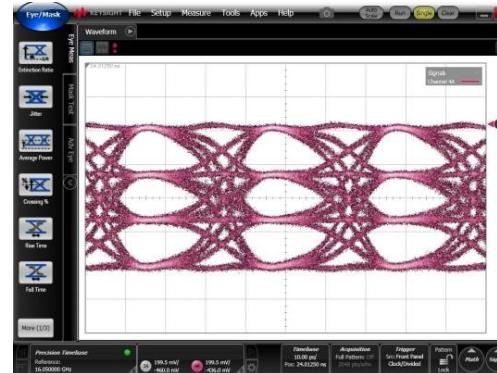
- **MZ1834B**

28 Gbaud, 1.318 V
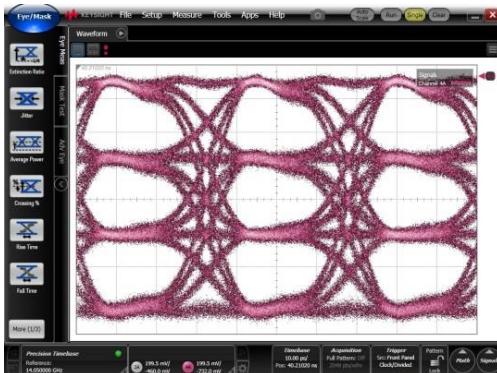
32.1 Gbaud, 1.318 V
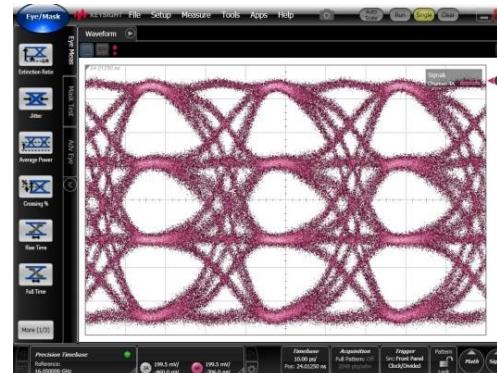
Measured with J1439A 80 cm cable +41V-6 Attenuator + 70-GHz Band Oscilloscope.

Anritsu envision : ensure

PAM4 Signal Generation (5)

➢ Typical MZ1838A PAM4 waveforms
 3 Eye Independent Level Control supports transmitter linearity test and stressed receiver test.

26.5625 Gbaud QPRBS13, 0.5 Vp-p   32.1 Gbaud QPRBS13, 0.5 Vp-p
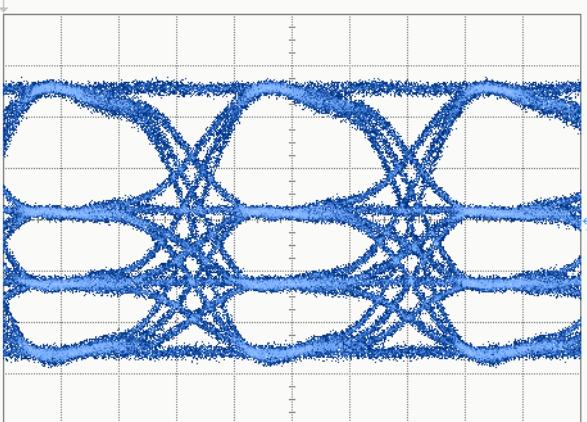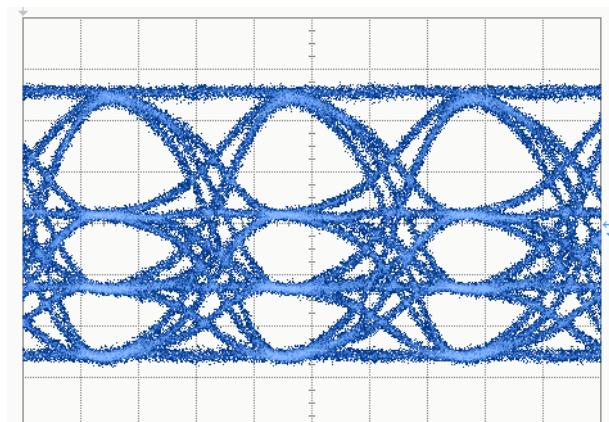
Example of Wide Upper Eye Opening

Example of Wide Lower Eye Opening


Anritsu envision : ensure

13
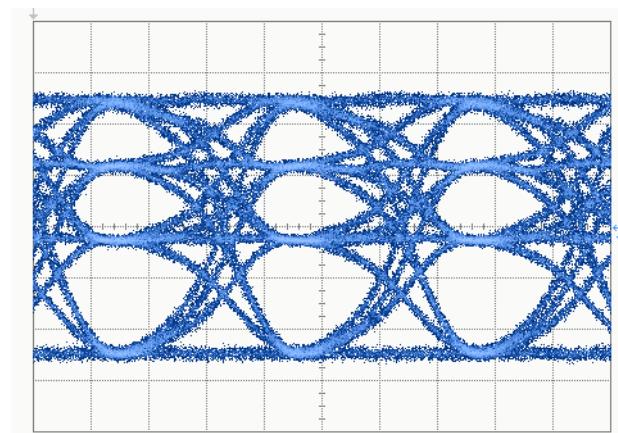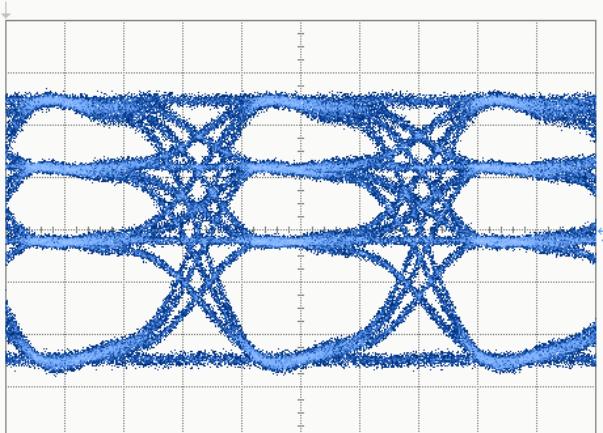
PAM4 Signal Generation (6)

➢ Typical G0375A PAM4 waveforms

28 Gbaud, 2.0 Vp-p, PRBS13Q
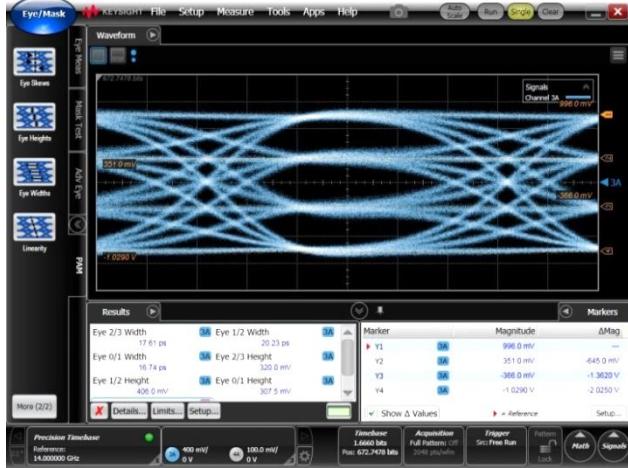
28 Gbaud, 0.9 Vp-p, PRBS13Q
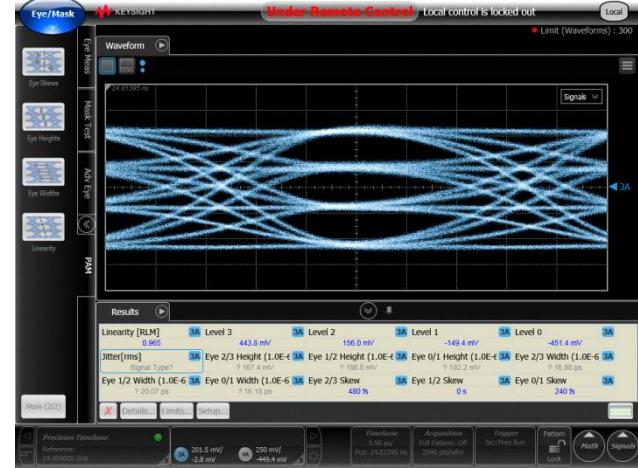
25 Gbaud, 2.0 Vp-p, Linearity control
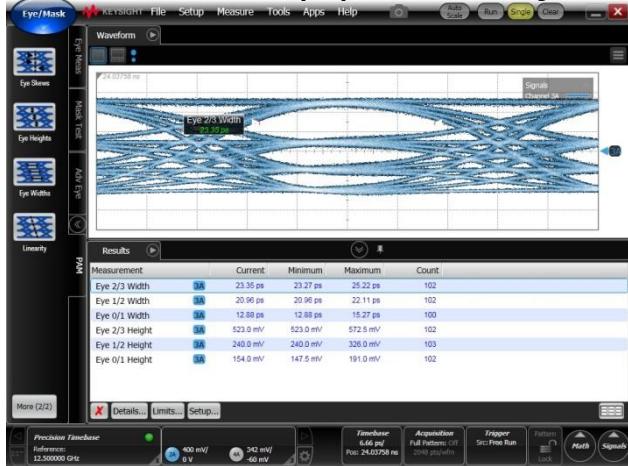
Measured with J1728A 40-cm cable + 41V-20 Attenuator + 70-GHz band oscilloscope

Anritsu envision : ensure

PAM4 Signal Generation (7)

➢ PAM4 Signal level and pattern control using PAM control software
  - Independent control of Upper, Middle, Lower Eye amplitude (using G0375A or MZ1838A)
  - Pattern settings using PAM control software
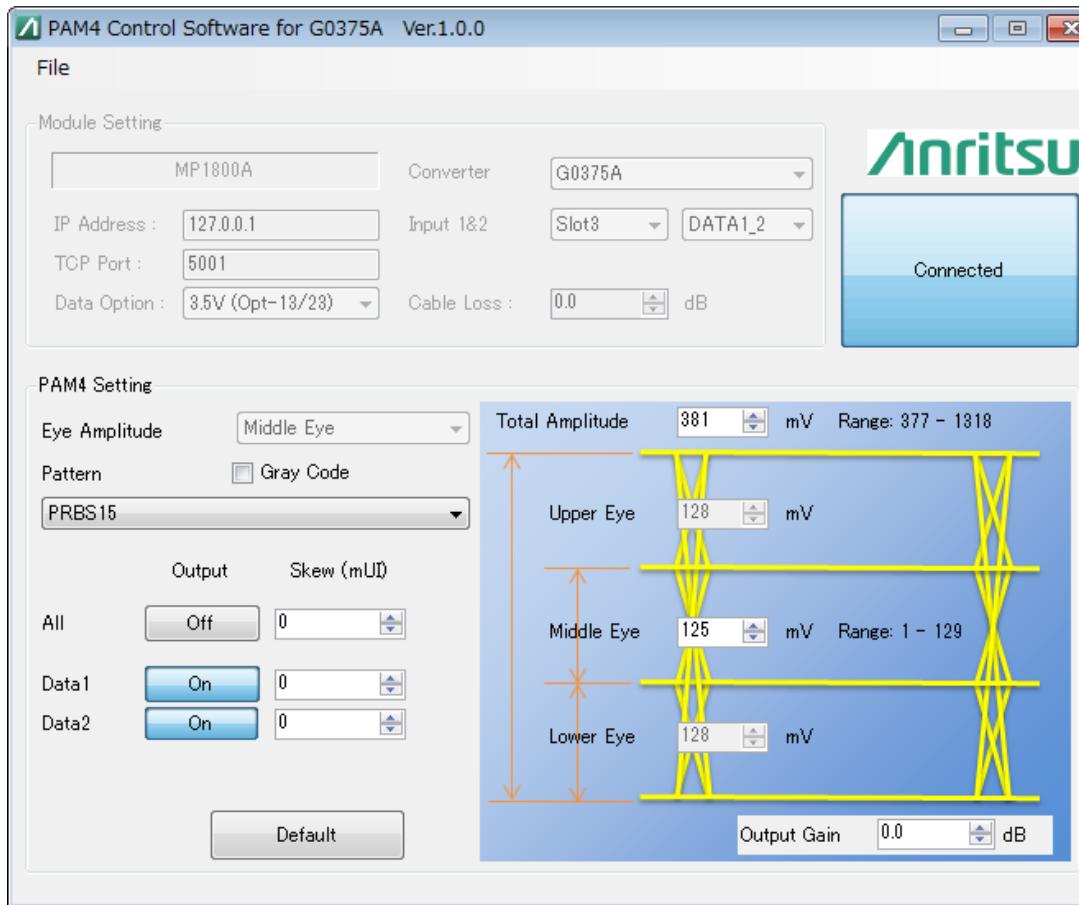
PAM4 Signal Generation (8)

➢ 64-Gbaud PAM4 signal generation (G0374A + MU18302xA PPG (4 ch))
Supports 64-Gbaud rates with minimum additional investment costs in instruments

J1612A x 4

32 Gbit/s Data1A,1B (MSB)

G0374A
64Gbaud PAM4 DAC

32 GHz Clock input

Data1 Data2

J1611A

DUT

Data3 Data4

32 Gbit/s Data0A,0B (LSB)

64 Gbaud PAM4
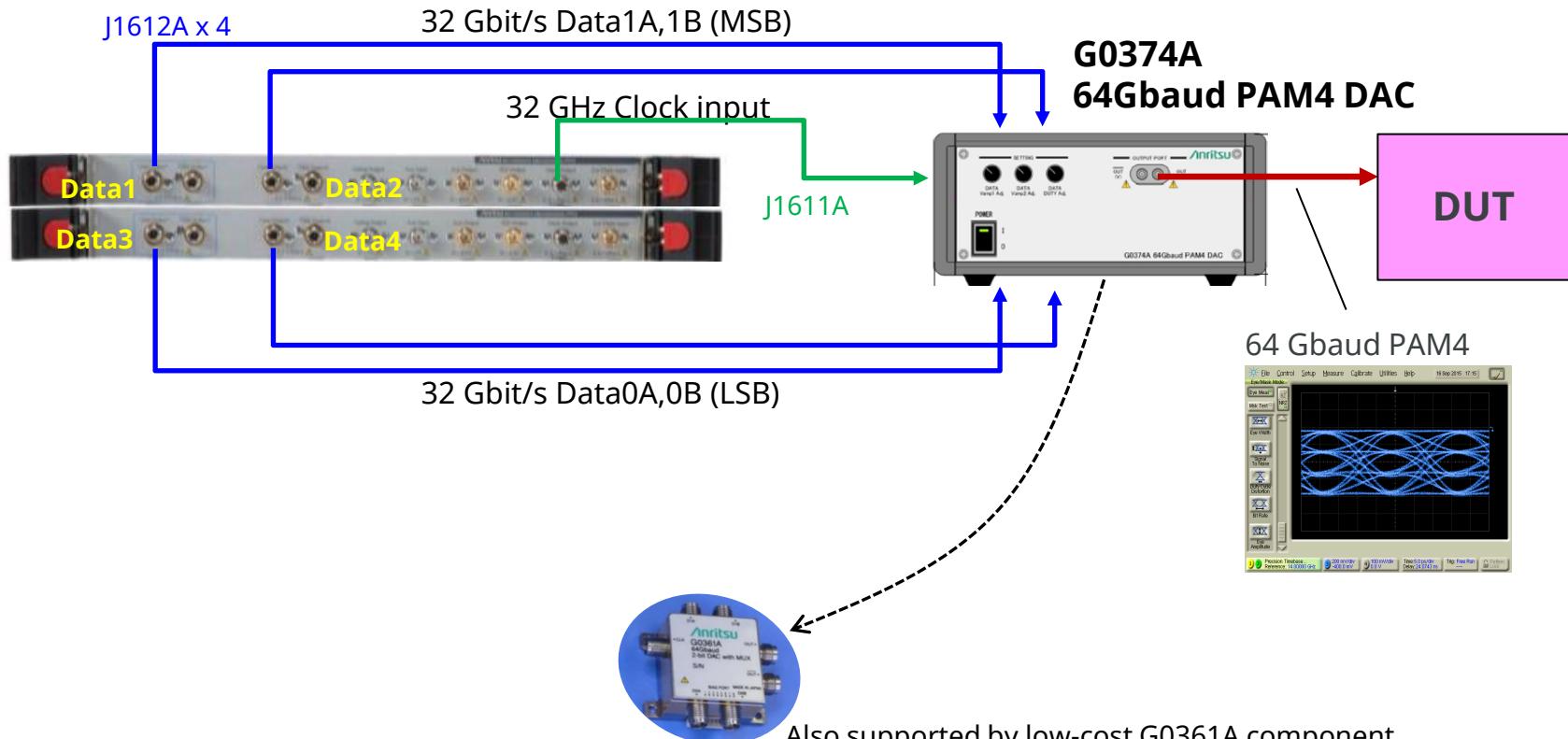
Also supported by low-cost G0361A component.
In this case, requires adjustment using separate external power source as well as coaxial cables.

Anritsu envision : ensure

PAM4 Signal Generation (9)

➢ G0374A/G0361A Typical Waveforms (Measured with 41V-6 Attenuator + 34VV50 Adapter + 70-GHz band oscilloscope)

Implements high-accuracy and high-reproducibility measurements using fast Tr/Tf waveforms with low Intrinsic Jitter

- **PAM4**

  ### 64 Gbaud
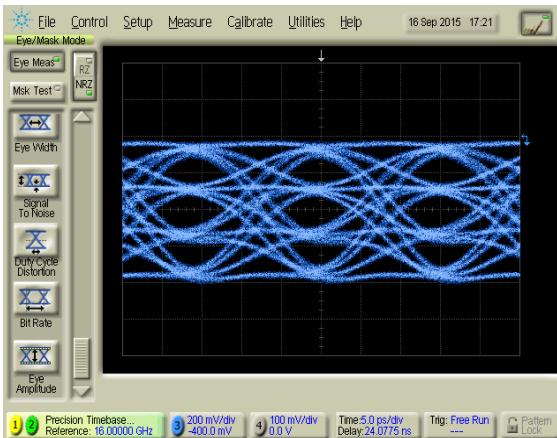
  ### 56 Gbaud
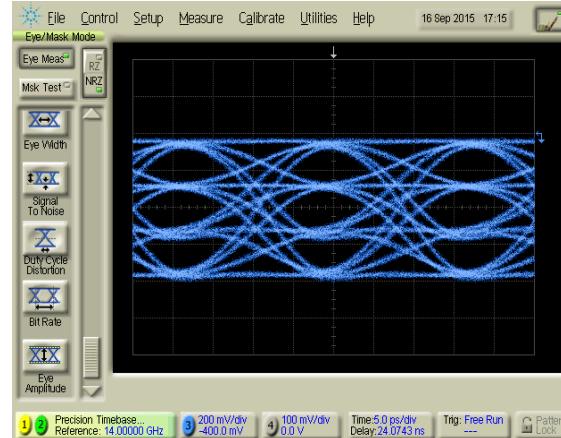
  ### 28 Gbaud
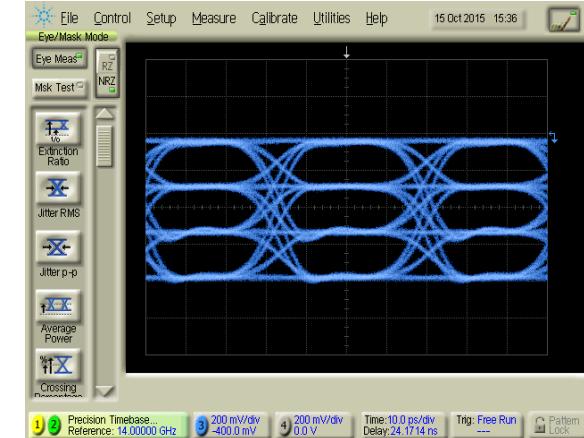
- **NRZ**

  ### 64 Gbaud
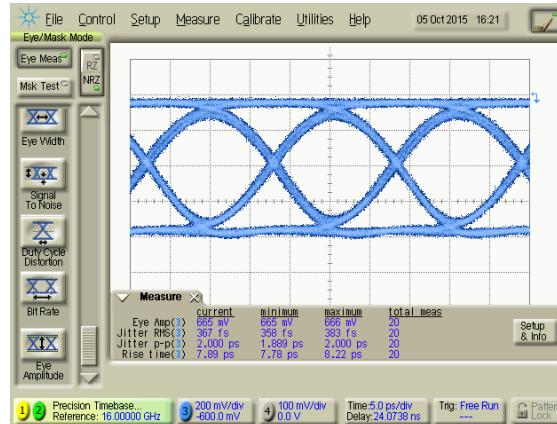
  ### 56 Gbaud

  ### 56 Gbaud 2Tap Emphasis

Anritsu envision : ensure
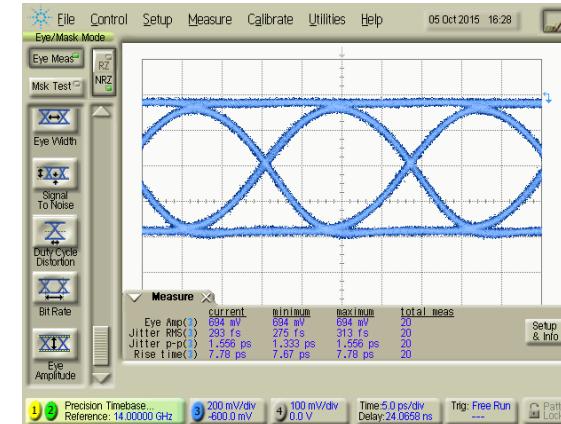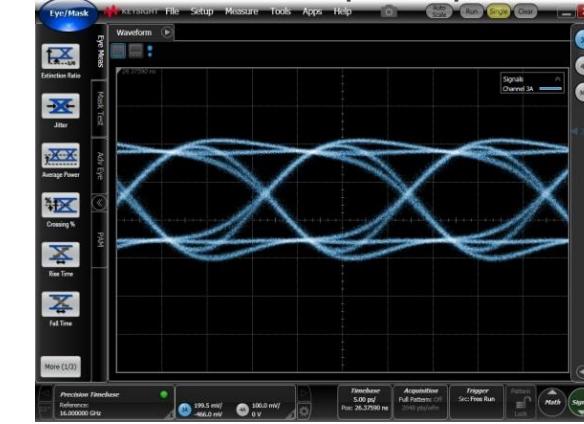
PAM4 BER Measurements using MP1800 Series (1)

- High-input sensitivity BER detection (Eye Height 10 mV @ 28.1 Gbaud, 25 mV @ 56.2 Gbaud) supports efficient verifications
- Supports 56-Gbaud BER measurements*

	32 Gbaud BER Measurements MU183040B or MU183041B 28 G/32 Gbit/s High Sensitivity ED	64 Gbaud BER Measurements MP1862A 56 G/64 Gbit/s DEMUX + MU183040B 28 G/32 Gbit/s High Sensitivity ED
Baud Rate	2.4 to 32.1 Gbaud (4.8 to 64.2 Gbit/s)	4.8 to 56* Gbaud (9.6 to 112 Gbit/s)
Data Input	Differential Input Input Amplitude 1.0 Vp-p maximum	
Input Sensitivity	MU18304xB Data Input 10 mV (typ.) Eye Height @ 28.1 Gbaud	MP1862A Data Input 25 mV (typ.) Eye Height @ 56.2 Gbaud
Measurement Method	3 Eye sequential measurement using 1ch ED, or simultaneous measurement using 3ch ED	3 Eye manual measurement using 1ch ED

*PRBS15 patterns to 56 Gbaud (typ.) and error free with G0374A/G0361A-MP1862A

Anritsu envision : ensure

PAM4 BER Measurements using MP1800 Series (2)

➢ BER measurement setup using MP1800A series
• PAM4 signal generation by combining 2ch NRZ signals

| PPG1 | 0 0 2 2 2 0 2 0 . . . | (MSB) |

| PPG2 | 0 1 0 1 0 0 1 1 . . . | (LSB) |

| PAM4 | 0 1 2 3 2 0 3 1 . . . |

• PAM4 BER Measurement
Each of Upper, Middle, Lower Eye openings recognized as H or L by observing two NRZ signal levels

| ED1: Threshold for upper eye | 0 0 0 1 0 0 1 0 . . . | (LSB pattern for "2" and "3" levels) |

| ED2: Threshold for middle eye | 0 0 2 2 2 0 2 0 . . . | (MSB pattern) |

| ED3: Threshold for lower eye | 0 1 1 1 1 0 1 1 . . . | (LSB pattern for "0" and "1" levels) |
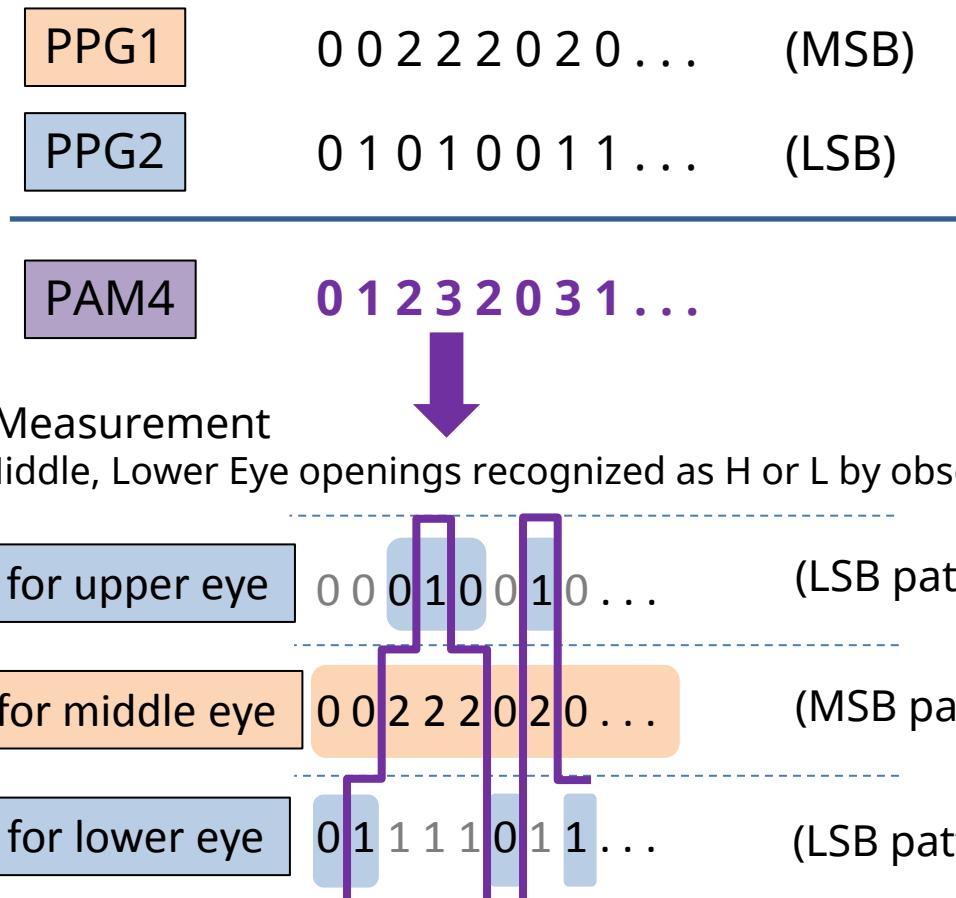
↑ED1, 2, 3 measure simultaneously using 3ch ED or sequentially using 1ch ED

The 3 Eye Rx pattern is set based on the PPG1 (MSB), and PPG2 (LSB) patterns. LSB "2" and "3" levels measured by ED1 and "0", and "1" levels measured by ED3.

PAM4 BER Measurements using MP1800 Series (3)

- PAM4 BER measurement using 32-Gbaud 3ch ED:

The BER of the PAM4 3 Eye (Upper/Middle/Lower) pattern is measured accurately in real-time using the 3ch ED and redundant bit Mask function, and the total BER result is calculated.

- Error Detector excellent sensitivity 10mv

MU18304xB 4ch ED

MP1800A 2ch PPG

NRZ Data CH1

NRZ Data CH2

MZ1834A 4PAM Converter

Differential 4PAM Signal

Upper Eye

Middle Eye

Lower Eye

BER for each channel and Total BER displayed on one screen

Vth_Upper

Vth_Middle

Vth_Lower

Anritsu envision : ensure
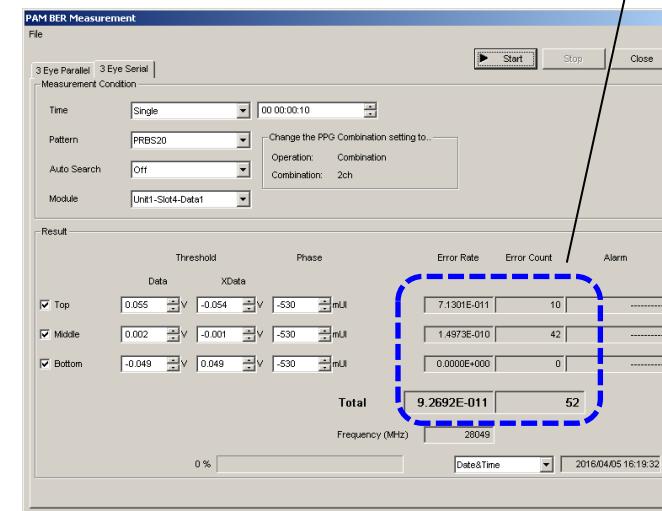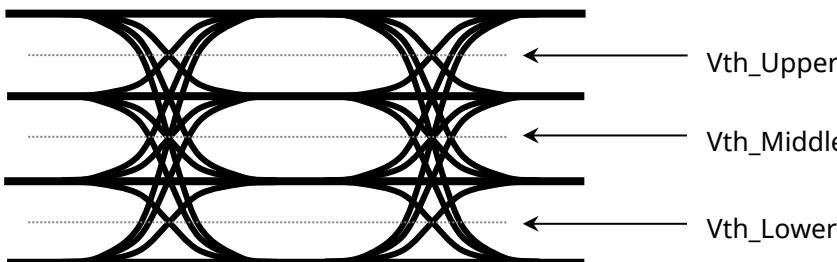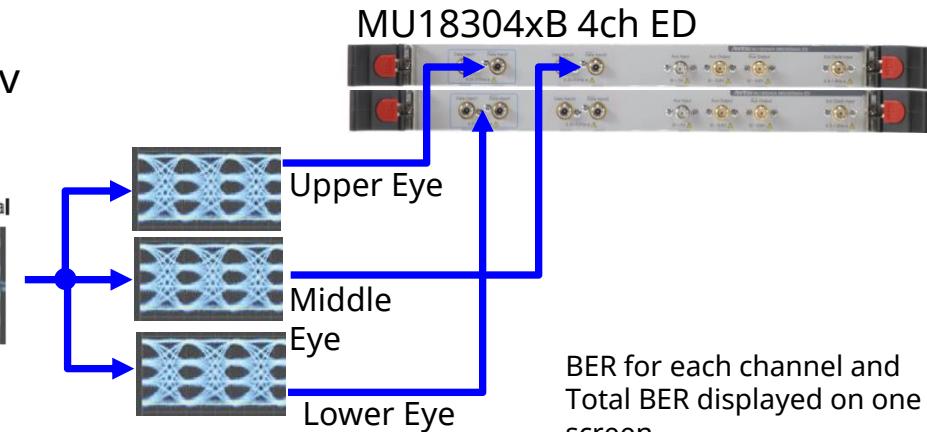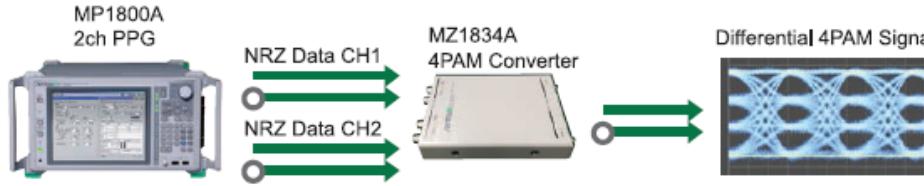
PAM4 BER Measurements using MP1800 Series (4)

➢ BER Measurement using 32-Gbaud 1ch ED:

• BER measurement is performed continuously by auto-searching using a 1ch ED and the PAM4 3 Eye (Upper/Middle/Lower) sampling method. This is a low-cost PAM BER measurement method for calculating the total BER.

• Measurement leverages 32G ED high-input sensitivity performance (10 mV typ. Eye Height).

• PAM4 BER is measured using the Clock Recovery function.

MU183040B 1ch ED

MP1800A 2ch PPG

NRZ Data CH1

NRZ Data CH2

MZ1834A 4PAM Converter

Differential 4PAM Signal
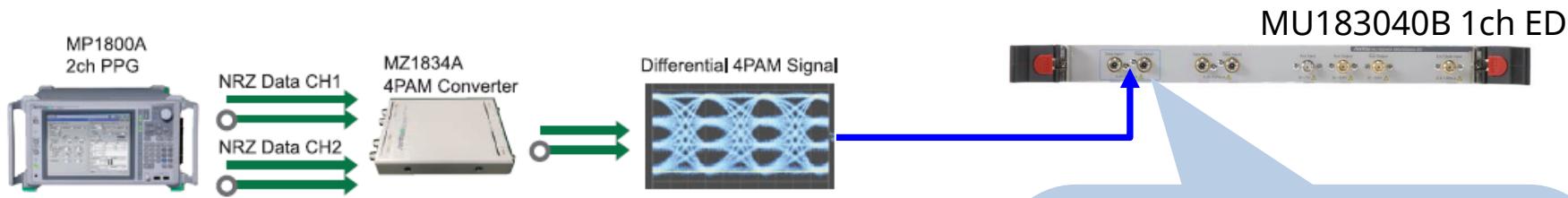
Example of Measurement using Clock Recovery Function

Recover Clock from Data1 Input signal Middle Eye pattern.
Measure BER of Data2 Input signal sequentially at 3 Eyes.

MU183040B 1ch ED
Opt-022 (2.4 to 28.1 Gbit/s Clock Recovery)

Data1   Data2

PAM4 Input Signal

Differential 4PAM Signal

Recover Clock from Data1 input signal

Threshold Voltage

Pattern

BER Count

Sequential control

(1) Upper Eye
↓
(2) Middle Eye
↓
(3) Lower Eye

Anritsu envision : ensure
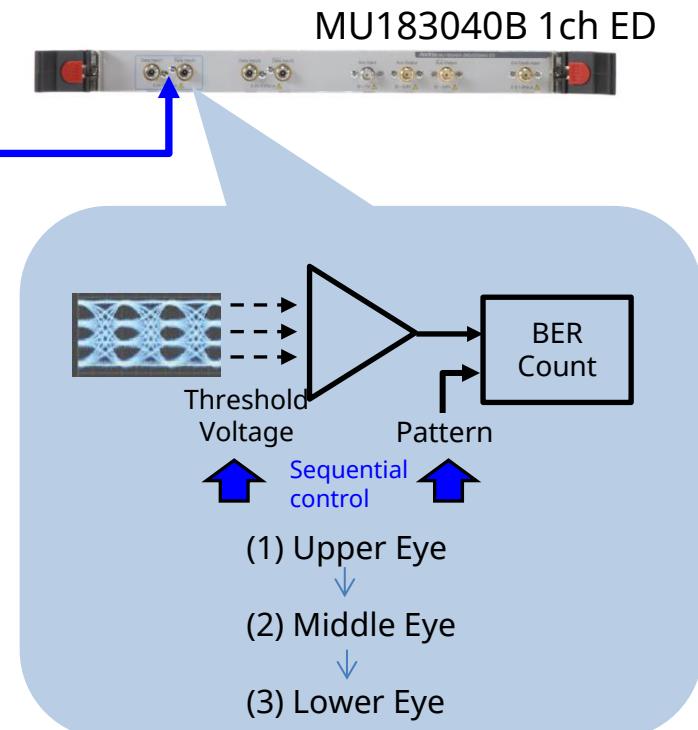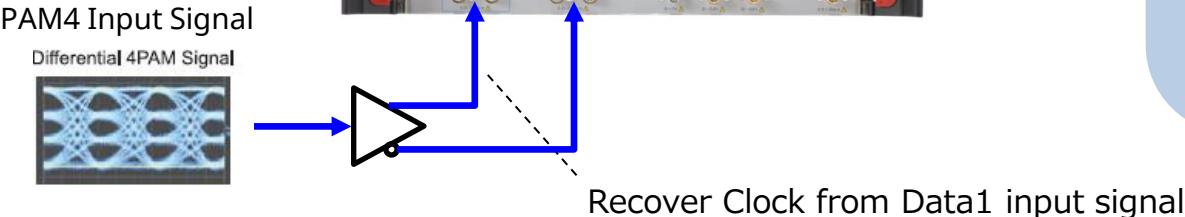
PAM4 BER Measurements using MP1800 Series (5)

G0376A 32Gbaud Decoder with CTLE supports PAM4 True BER measurement

- 32 Gbaud <u>PAM4 True BER Measurement</u>
- <u>High Input Sensitivity</u> (Eye Height 40 mV @ 28 Gbaud)
- <u>Tunable CTLE</u> (Gain –12 to 0 dB)
- <u>CDR Function</u> (as set with MU183040B-022)

MP1800A SQA
32 Gbit/s 2 ch PPG,
32 gbit/s 2 ch ED

G0375A
32Gbaud Power
PAM4 Converter

MSB

LSB

MSB

LSB

G0376A
32Gbaud PAM4
Decoder with CTLE

DUT
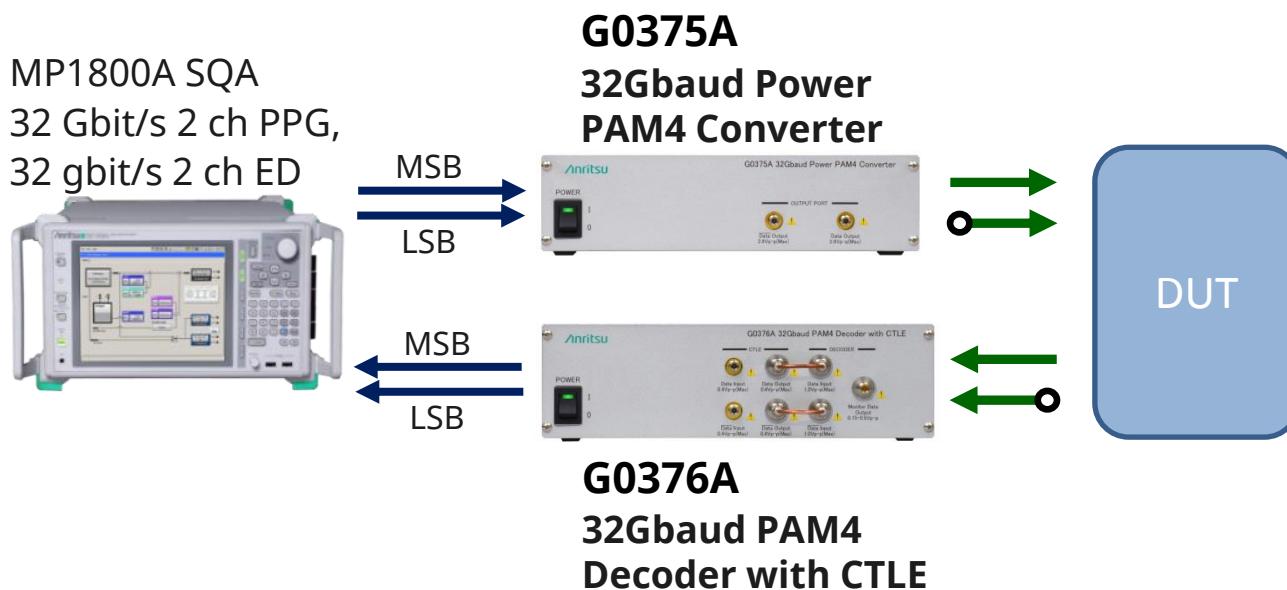
PAM4 BER Measurements using MP1800 Series (6)

➢ Combining 32G 2ch BERT (MSB/LSB) with PAM4 Converter/Decoder supports both NRZ and PAM4 BER measurements

| PPG1 | 0 0 2 2 2 0 2 0 . . . | (MSB) |

| PPG2 | 0 1 0 1 0 0 1 1 . . . | (LSB) |

⬇ (PAM4 Encode: **G0375A**)

| PAM4 | **0 1 2 3 2 0 3 1 . . .** |

⬇ (PAM4 Decode: **G0376A**)

| ED1 | 0 0 1 1 1 0 1 0 . . . | (MSB) |

| ED2 | 0 1 0 1 0 0 1 1 . . . | (LSB) |

Λnritsu envision : ensure
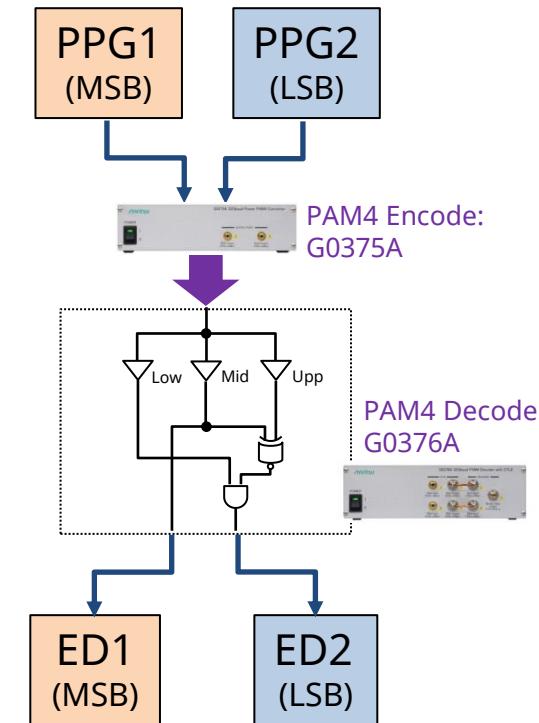
PAM4 BER Measurements using MP1800 Series (7)

➢ 56-Gbaud PAM4 BER Measurement:
• Supports high-baud-rate BER measurement
• Supports accurate and high-reproducibility measurement using 56/64Gbit/s DEMUX MP1862A with high input-sensitivity performance (25 mV typ. Eye Height)

MP1800A Signal Quality Analyzer

MU183020A 32G 2ch PPG x 2

MU181000B Synthesizer

MU183040B 32G 2ch ED

J1612A x 4

28 Gbit/s Data1A, B (MSB)

28 GHz CK

J1611A

28 Gbit/s Data 0A, B (LSB)

G0374A 64 Gbaud PAM4 DAC

64 Gbaud PAM4

MP1862A 64G DEMUX

DUT

BER at each three settings measured individually by MP1862A

Anritsu envision : ensure
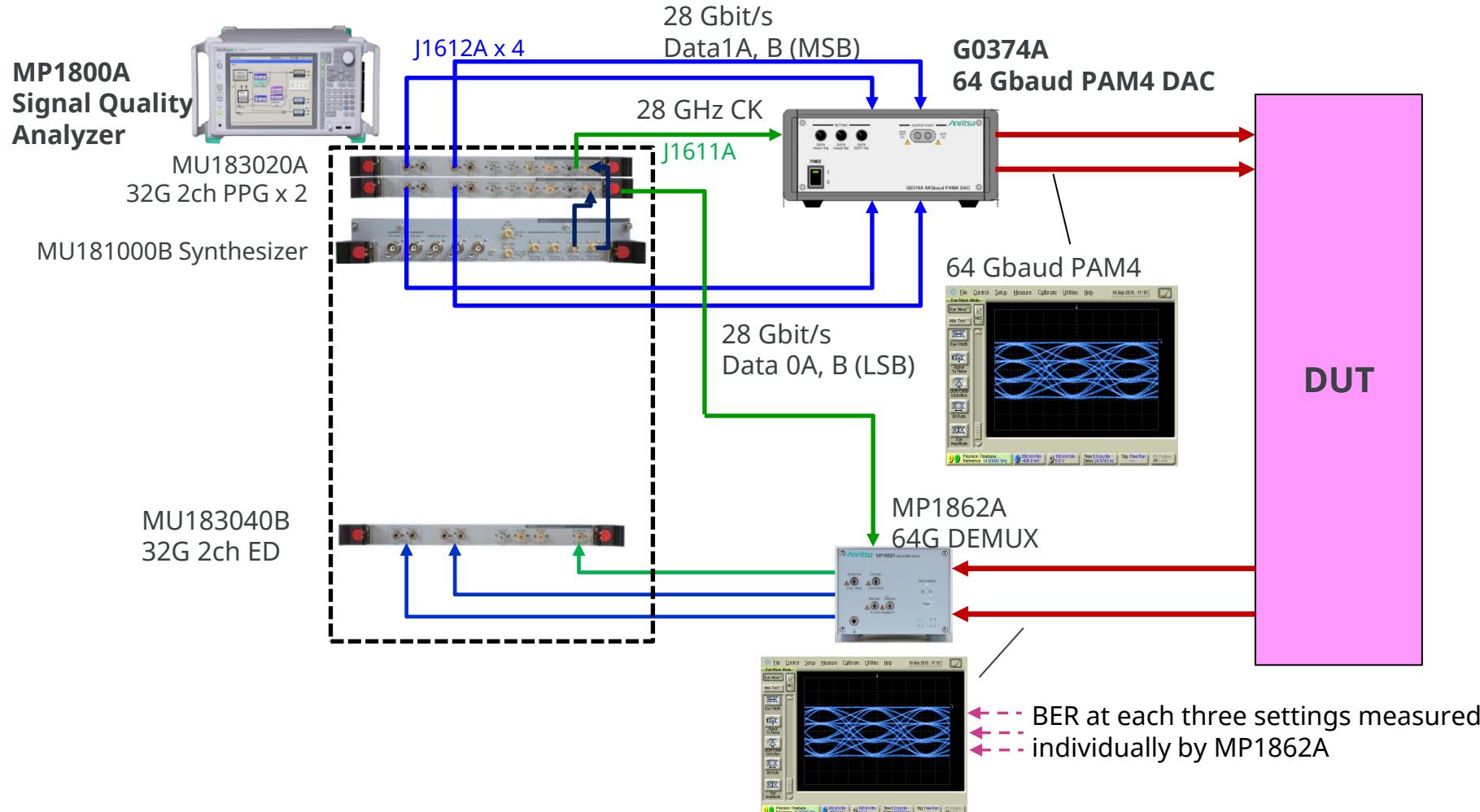
PAM4 BER Measurements using MP1800 Series (8)

➤ Supported Test Patterns

Supported Test Patterns
PRBS
PRBS13Q, PRQS10
Gray PRBS13Q
SSPR
JP03A, JP03B
Square
Transmitter Linearity Test Pattern

➤ Details

PRBS 7, 9, 10, 11, 15, 20, 23*,31* (*PPG and G0376A with ED support)

PRBS13Q, PRQS10: Quaternary Sequence Patterns

These patterns are defined as PAM4 test patterns because they are easily generated from PRBS generation circuits and PAM4 has about the same randomness as PRBS

Gray PRBS13Q:

This pattern is for evaluating the Transmitter Output and Receiver Input amplitude, Eye Height, Eye Width, VEC (Vertical Eye Closure) defined by CEI-56G-VSR-PAM4 using an oscilloscope. The pattern length (8191 bits) can be captured by an oscilloscope and high-order randomness can be selected.

Although PAM4 signals have four levels implemented as 2-bit pairs, sometimes a 2-bit change such as 01 to 10 is wrongly detected for a 1 level change. To prevent this, the Tx side uses a Gray code (00→00, 01→01, 10→11, 11→10) and the Rx side uses the opposite Gray decode.

PAM4 BER Measurements using MP1800 Series (9)

SSPR (Short Stress Pattern Random) **:**

This 32,762-bit pattern is defined by CEI 3.1. The pattern length is equivalent to PRBS15 and it is used as a PAM4 evaluation pattern due to its features as a high-stress test signal.

JP03A:

This "0303…" pattern string is used for evaluating Transmitter RJ.

JP03B:

This 62-symbol pattern has 15 repetitions of "03" followed by 16 repetitions "30".

03030303030303030303030303030303030303030303030303030303030303030

It is used for evaluating Transmitter Even-Odd Jitter.

Square:

This "3333333300000000" pattern string is for Optical Modulation Amplitude (OMA) evaluation of optical interfaces.

Transmitter Linearity Test Pattern:

PRBS13Q pattern is used for RLM measurement.

R_{LM} = min((3 x ES1), (3 x ES2), (2 – 3 x ES1), (2 – 3 x ES2))   (120D-5)

V_{mid} = $(V_0 + V_3)$/2, ES1 = $(V_1 – V_{mid})$/$(V_0 – V_{mid})$,   ES2 = $(V_2 – V_{mid})$/$(V_3 – V_{mid})$

Anritsu envision : ensure

Main Applications (1)

- Evaluation of 28-Gbaud TOSA/ROSA in 400GbE Transceiver
  - MU183020A 32G PPG High-quality waveforms
  - PAM4 Linearity control
  - PAM4 BER margin measurement using high-input sensitivity 32G ED

High Amplitude (DML ~1 V, EAM ~2 V)
High-Quality Input Waveform

G0375A
32Gbaud Power PAM4 Converter

28G NRZ x 2, or x 3

LD

Scope

TIA

PD

MP1800A
MU183020A 32G PPG (2ch or 3ch)
MU183040B 32G ED (1ch)

Anritsu envision : ensure
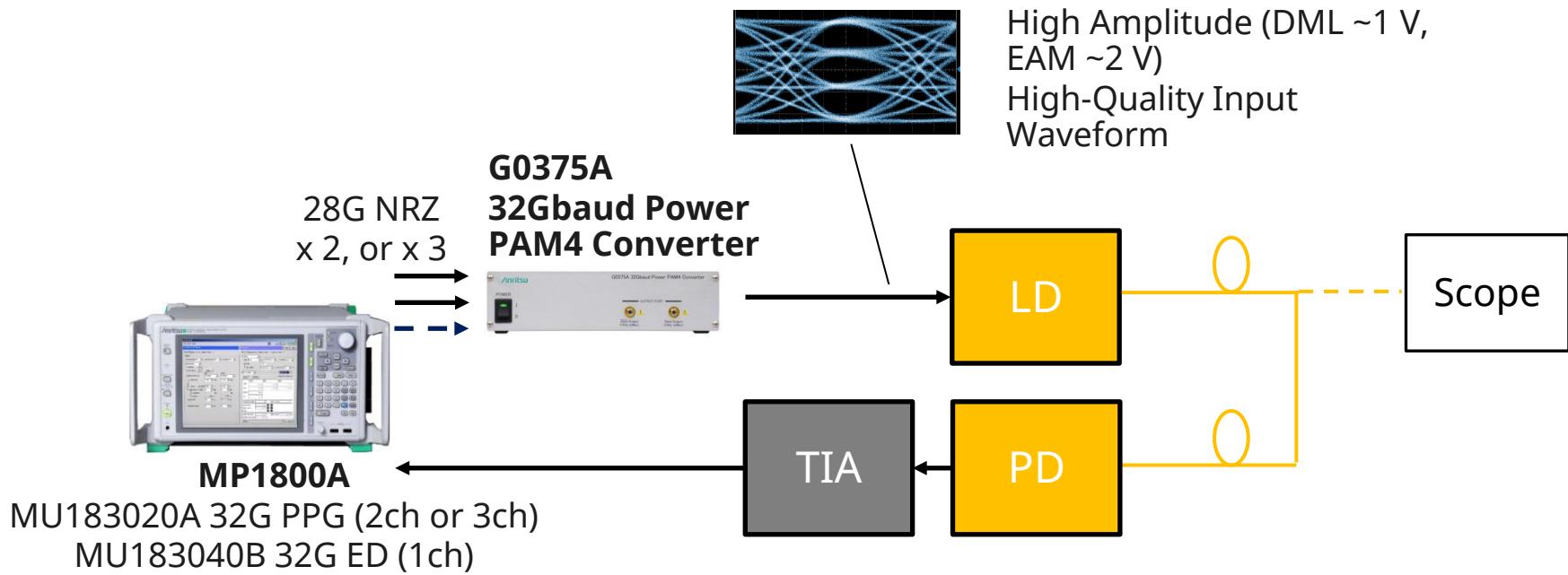
Main Applications (2)

- Evaluation of 400 GAUI-8 in 400GbE Transceiver
  - 8ch PAM4 multichannel and expansion
  - Supports crosstalk validation

MP1800A x 2
MU183021A 32G PPG (4ch) x 4

28G NRZ x 16

G0375A x8

28 Gbaud PAM4 x 8

LD

x8

WDM MUX

x8

28 Gbaud PAM4 x 8

TIA

PD

WDM DEMUX

MP1800A
MU183041B 32G ED (4ch) x 2
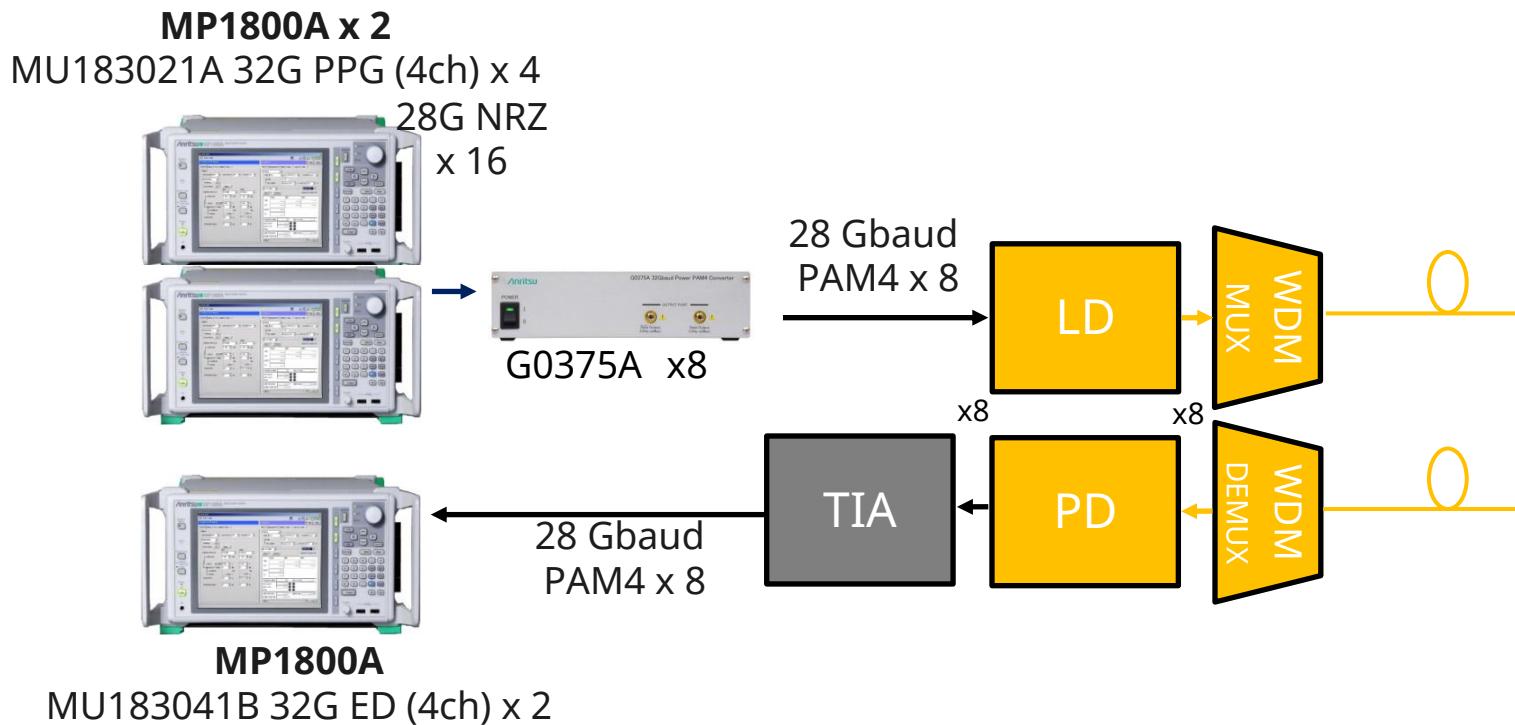
Main Application (3)

> Supports 400GAUI-8, and CEI-56G-VSR-PAM4 Electrical I/F Rx tests

- ・Low-Jitter PAM4 waveform
- ・4Tap Emphasis function
- ・Jitter Addition function RJ/BUJ/SJ
- ・CTLE (14 GHz peak frequency)
- ・CDR function (as set with MU183040B-022)

MP1800A

MU183020A 32 G 2 ch PPG
MU183040B 32 G 2 ch ED
MU181500B Jitter
MU181000B Synthesizer
MX183000A JTOL software

MP1825B
Emphasis

**G0375A
32Gbaud Power
PAM4 Converter**

Artek
ISI generator

PAM4
Transceiver,
Re-timer

**G0376A
32Gbaud PAM4
Decoder with CTLE**