

High-Speed PAM Signal Generation and BER Measurements

Signal Quality Analyzer MP1800A Series

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1. Introduction

The next-generation 200 and 400-Gbits/s transmission methods defined by IEEE802.3bj, 100GBase-KP4, and IEEE802.3bs increase the transmission capacity compared to the conventional NRZ method without increasing the symbol rate by implementing Pulse Amplitude Modulation (PAM) transmission technology.

In PAM4 signalling, instead of transferring 1 bit at one of two levels of 0 or 1 in one time slot as in NRZ signalling, two bits of data are transferred at four levels in one time slot. In PAM8 signalling, three bits of data are transferred at eight levels in one time slot. PAM has the merit of increasing the data transfer capacity without increasing the signal symbol rate, but conversely, since the voltage level of each signal in one time slot becomes smaller, it has the demerit of a poorer signal to noise ratio (SNR).

This Application Note explains generation of PAM signals with the above-described features as well as BER measurement methods.

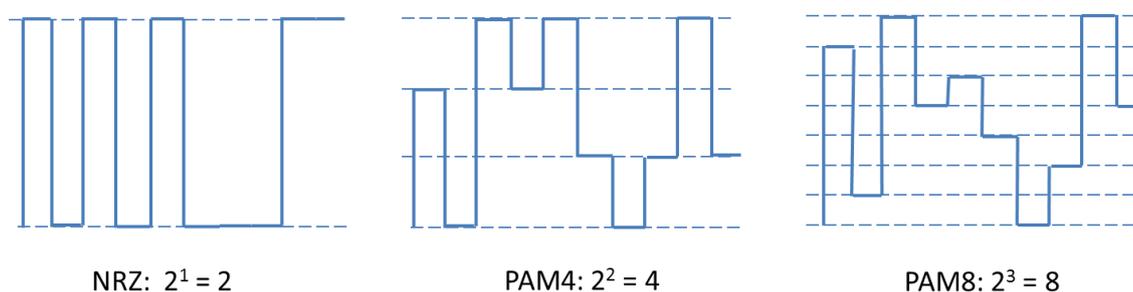


Fig. 1.1 Signal Transmission Methods and Data Volumes

Table 1.1 lists the trend in transmission methods used by the latest 100G, 200G, and 400G standards.

Table 1.1 Transmission Methods used by Each Standard

Standard	Format	Baud rate	Standard	Format	Baud rate		
400G	400G BASE-SR16	NRZ	26.6G	100G	100G PSM4	NRZ	25.8G
	400G BASE-DR4	PAM4	53.1G		CWDM4/CLR4	NRZ	25.8G
	400G BASE-FR8	PAM4	26.6G		100G BASE-LR4	NRZ	25.8G
	400G BASE-LR8	PAM4	26.6G		100G BASE-ER4	NRZ	25.8G
	CDAUI-16	NRZ	25.8G		100G BASE-CR4	NRZ	25.8G
	CDAUI-8	PAM4	26.6G		100G BASE-KR4	NRZ	25.8G
200G	200G BASE-SR8	NRZ	26.6G		100G BASE-KP4	PAM4	13.6G
	200G BASE-SR4	PAM4	26.6G		CAUI-10	NRZ	10.3G
	200G BASE-FR4	PAM4	26.6G		CAUI-4	NRZ	25.8G
	200G BASE-LR4	PAM4	26.6G		50G	50G BASE-SR	PAM4
	CCAUI-8	NRZ	25.8G	50G BASE-FR		PAM4	26.6G
CCAUI-4	PAM4	26.6G	50G BASE-LR	PAM4		26.6G	
100G	100G BASE-SR10	NRZ	10.3G	50GAUI	PAM4	26.6G	
	100G BASE-SR2	PAM4	26.6G	25G	25G BASE-SR	NRZ	25.8G
	100G BASE-SR4	NRZ	25.8G		25G BASE-FR	NRZ	25.8G
	100G SWDM	NRZ	25.8G		25G BASE-LR	NRZ	25.8G
			25GAUI		NRZ	25.8G	

PAM4, which has been the main standard in recent years, has a transmission speed of 26.6 Gbaud, but some 53.1 Gbaud PAM4 transmissions such as 400GBase-DR4, are being adopted for 400G.

2. PAM Signal Generation

This section describes PAM4 and PAM8 signal generation methods as well as points to note at signal generation. As shown in Fig. 1.1, PAM4 transfers data for 4 values in one time slot whereas PAM8 transfers data for 8 values. Consequently, PAM4 (2^2) signalling uses two Pulse Pattern Generators (PPG) as the data signal source, and PAM8 (2^3) uses three PPGs. Figure 2.1 shows the setup for PAM4 and PAM8 signal generation. The basic setup uses a passive method in which the Data signal output from a multi-channel PPG is combined using a Power Divider. The Anritsu solution makes it easy to generate high-quality PAM4 signals, because it provides the multi-channel PPG, 4PAM Converter, 8PAM Converter and waveform adjustment software.

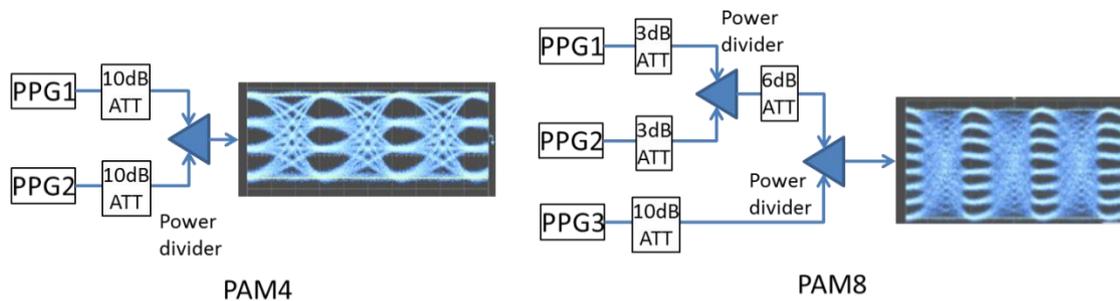


Fig. 2.1 Basic Setup for PAM Signal Generation using Passive Method

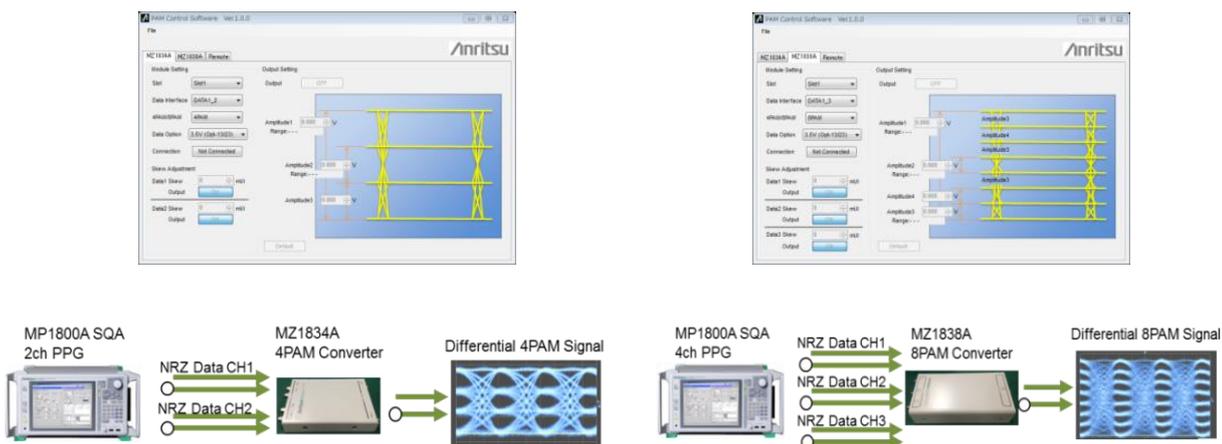


Fig. 2.2 Anritsu PAM Signal Generation Solution

In this setup, the multi-channel PPG requires:

- (a) Function for varying data phase between channels with high accuracy
- (b) High-quality waveforms (low jitter, low waveform distortion, high-speed Rise and Fall times)

To reduce the PAM signal jitter, the phase of the data between the multiple PPGs used to generate the PAM signal must have the exact same timing. From Table 1, the width of 1 bit at 26.6 Gbaud PAM4 signal transmission is 37.5 ps, corresponding to a short electrical length of about 7.9 mm, so a difference of just a few mm has a great impact on the waveform quality. Consequently, as described in item (a) above, the multi-channel PPG must have a function for precise adjustment of the data phase between channels.

In addition, as described in (b), obtaining a high-quality PAM signal requires that the PPG itself generates high-quality waveforms. If the PPG jitter is large, the PAM signal jitter will also be large, and if the waveform distortion is large, the SNR is degraded by the large signal baseline. Any delay in the rise and fall times has a direct impact on reduction of the phase margin and increased PAM signal jitter and

degraded SNR.

For more details about PAM signal generation, refer to the Anritsu Application Note entitled 'QAM Transmission with using PAM Signal'

(<https://www.anritsu.com/en-US/test-measurement/support/downloads/application-notes/dwl009955>).

In addition, Anritsu also has the G0374A 64 Gbaud PAM4 DAC supporting 53.1 Gbaud PAM4 transmissions required by 400GBase-DR4 for 400G transmissions.

Since both the 32 Gbaud PAM Converter (MZ1834A, MZ1838A) and 64 Gbaud PAM4 DAC solutions have jitter transparency, they support addition of jitter to PAM4 signals and jitter tolerance tests.

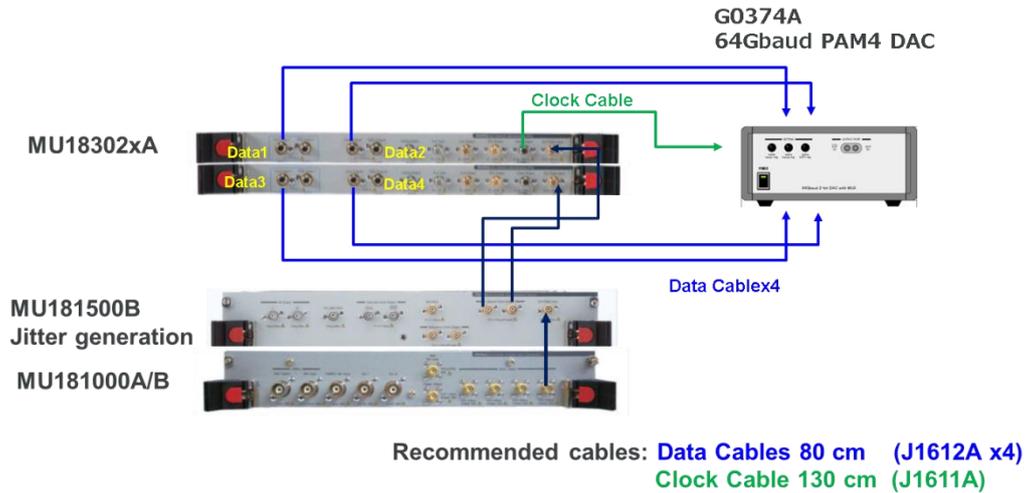


Fig. 2.3 Anritsu 64 Gbaud PAM4 Signal Generation Solution

3. PAM Signal BER Measurement

This section explains the methods for measuring the bit error rate (BER) of PAM4 signals generated as described in section 2.

Figure 3.1 shows the PAM4 signal generated from the PPG1 and PPG2 patterns. The horizontal parts of the waveform in the lower figure are called the Threshold, meaning the threshold voltage for evaluating the PAM4 amplitude. Since PAM4 uses four values, three threshold voltages are required to recognize each voltage.

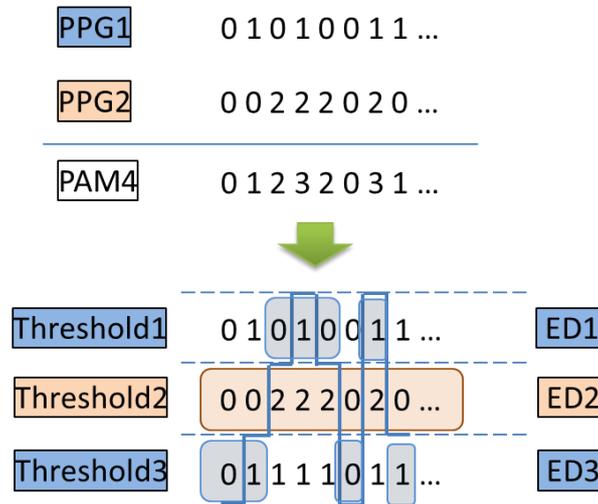


Fig. 3.1 PAM Signal and BER Measurement Threshold Relationship

The pattern for Threshold 2 is the same as the pattern of PPG2 generating the maximum amplitude at PAM generation. And the PPG1 pattern appears half in Threshold 1 and half in Threshold 3. The shaded blue parts in the waveform diagram are the PPG1 pattern. The PPG1 pattern appears at Threshold 3 when Threshold 2 = 0 (Low), and at Threshold 1 when Threshold 2 = 2 (High).

If the expected pattern at each Threshold is already known like this, the BER of the PAM signal can be measured by setting this pattern at the Error Detector (ED).

Since the data patterns for Threshold 1 and Threshold 3 are obtained by dividing the data pattern from one PPG into two, the measured BER is different from the true BER. The data pattern output from PPG1 is measured by two EDs corresponding to Threshold 1 and Threshold 3. If the PPG2 pattern mark ratio is assumed to be 1/2, the measurement target is 50% of each of the Threshold 1 pattern string and Threshold 3 pattern string. Consequently, if the PPG1 measurement result is the simple sum of Threshold 1 and Threshold 3, there is a possibility of the Error Count being too large due to inclusion of errors outside the measurement target.

This section describes the three requirements for measuring instruments used to measure PAM BER.

- 1) PAM signal BER measurement presupposes prior knowledge of the patterns set at each ED. Consequently, the multiple PPGs generating the PAM signal require the ability to synchronize bit patterns rather than just synchronize the clock to change the cross point at the same timing. Anritsu's MP1800A Signal Quality Analyzer PPG can adjust each pattern generation position of the user programmable patterns generated from the PPG by ± 128 bits and the PRBS pattern cycle can be shifted by either a $\frac{1}{2}$ or $\frac{1}{4}$ period. As a result, if a PRBS23 pattern is set at two PPGs, adjusting each PPG pattern by a half cycle makes it possible to generate a correlation-free PAM4 signal. Moreover, since the PPG pattern is known, the pattern can also be set easily at the ED side.
- 2) The second condition is the ED input sensitivity. Assuming transmission of a differential PAM4 signal with an amplitude of 1.2 Vpp, the single-ended voltage identification range for each ED is 1/3 of 600 mVpp, or 200 mVpp. In addition, when measuring BER simultaneously at each ED, the input signal must be split 3-ways by a power divider, etc. In this case, since the amplitude is 70 mVpp or

less after splitting by the power divider, the ED must have high input sensitivity.

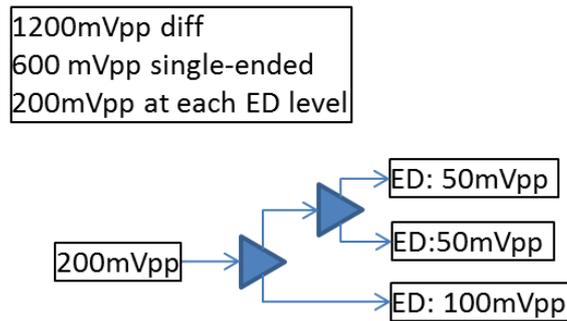


Fig. 3.2 Input Amplitude for Each ED

In other words, the ED must have the performance necessary for measurement of signals with an Eye Height of 30 or 40 mV. The Anritsu ED MU18304xB series can measure signals with an Eye Height of 10 mVpp (typical @ 28.1 Gbps) and the world's highest input sensitivity makes it ideal for measuring these types of small-amplitude signals.

However, PAM4 signals sometimes have Eyes with small amplitudes and degraded SNR, making them difficult to measure. In this case, rather than connecting a cascade of two power dividers as shown in Figure 3.2, the PAM4 Data is connected to the ED 1CH Data input and the PAM4 XData signal is split by a power divider and connected to the ED 2CH and 3CH for accurate measurement (Fig. 3.3).

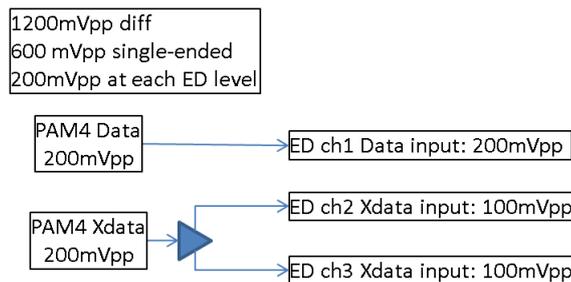


Fig. 3.3 PAM4 Measurement with Fewest Divider Stages

- The final condition is the requirement for a measurement mask function to remove items that are not the target of measurements from the pattern to ensure accurate BER measurement as described earlier. Specifying the measurement target part for each 1 bit when setting the ED pattern assures more accurate BER measurements.

When measuring PAM4 BER using three EDs as shown in Figure 3.1, the Total BER is found using the following equation:

$$\text{TherePAM4 BER} = \frac{\text{Error Count (Threshold2)} + \text{Masked Error count(Threshold1+Threshold3)}}{2 \times \text{Clock count (Threshold2)}}$$

4. Anritsu Solutions for PAM Signal Generation and BER Measurement

This section describes generation of 32- and 64 Gbaud PAM4 signals and BER measurement using actual Anritsu solutions.

4.1. 32 Gbaud PAM4 Solution

Table 4.1.1 lists the instruments used as the 28/32 Gbaud PAM4 Solution. It lists two system configurations: PAM4 Three Eye simultaneous measurement, and PAM4 Three Eye serial measurement.

Table 4.1.1 Instrument Configurations for 32 Gbaud PAM4 Solution

Model Number	Model Name	Required Option	Note	3 eye simultaneous measurement Qty.	3 eye serial measurement Qty.
MP1800A	Main Frame	002, 015, 032		1	1
MU181000A	Synthesizer			1	1
MU183020A	PPG (2ch)	023, 031		1	1
MU183041B	ED (4ch)	022 *3)	High Sensitivity 10 mV (eye height)	1	
MU183040B	ED (1ch or 2ch)	010 or 020	High Sensitivity 10 mV (eye height)		1
MZ1834B	4PAM Converter		K(m)x2 – K(f)x3	1	1
K240C	Power Divider		K(f)-K(f)-K(f)	1 *1)	
K241C	Power Splitter		K(f)-K(m)-K(f)	1 *1)	
J1439A *2)	Coaxial Cable 0.8m		K(m)-K(m) For ED - K241/0C	3	
Optional Parts					
J1551A (Optional)	Skew Matched Cables		Pair cable K(m)-K(m) Skew <3ps	1 *1)	1
K222B (Optional)	Adapter		K(f)-K(f)	2 *1)	

These configurations do not describe the cables required for connection with the DUT.

*1 Single-end measurement; differential signal measurement requires double the quantities.

*2 Single-end measurement; differential signal measurement requires the same number of J1551A Skew Matched Cables.

*3 Add when Clock Recovery required.

The Three Eye simultaneous measurement system is described first.

One two-channel MU183020A module is installed as the PPG. The Data and XData outputs of the two-channel PPG module are connected directly to the MZ1834B to generate the PAM4 signal.

PAM4 signal settings such as amplitude, offset, etc., are made using the PAM Application Software, which can be downloaded from the following Anritsu web sites.

Japan: <http://www.anritsu.com/ja-IP/test-measurement/support/downloads/software/dwl17288>

USA: <https://www.anritsu.com/en-us/test-measurement/support/downloads/software/dwl17288>

Europe: <https://www.anritsu.com/en-gb/test-measurement/support/downloads/software/dwl17288>

ASIA: <https://www.anritsu.com/en-au/test-measurement/support/downloads/software/dwl17288>

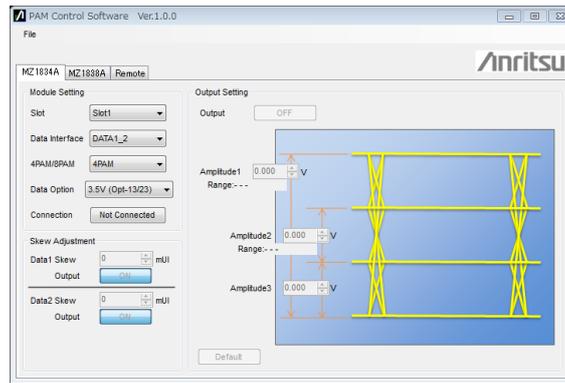


Fig. 4.1.1 PAM Signal Setting Software

The PAM4 signal used for Three Eye simultaneous measurement is split into three using the K240C and K241C power dividers. Since three channels are required, the MU183041B 4CH High Sensitivity ED with four channels in one module is used as the ED. When using Clock Recovery at measurement, the PAM4 Middle Eye threshold value is set at ED 1CH and the Top and Bottom Eye are measured at 2CH and 3CH. This is done because the MU183041B Clock Recovery circuit is connected to the input of 1CH and the Middle Eye with a 50% ratio of 0s and 1s is best for the Clock Recovery input. For reference, when generating PAM4 with PRBS, the Top Eye percentage of 0s is 75% and the Bottom Eye percentage of 1s is 75%, neither of which is suitable for use as the Clock Recovery input signal. Figure 4.1.2 shows the Three Eye simultaneous measurement system.

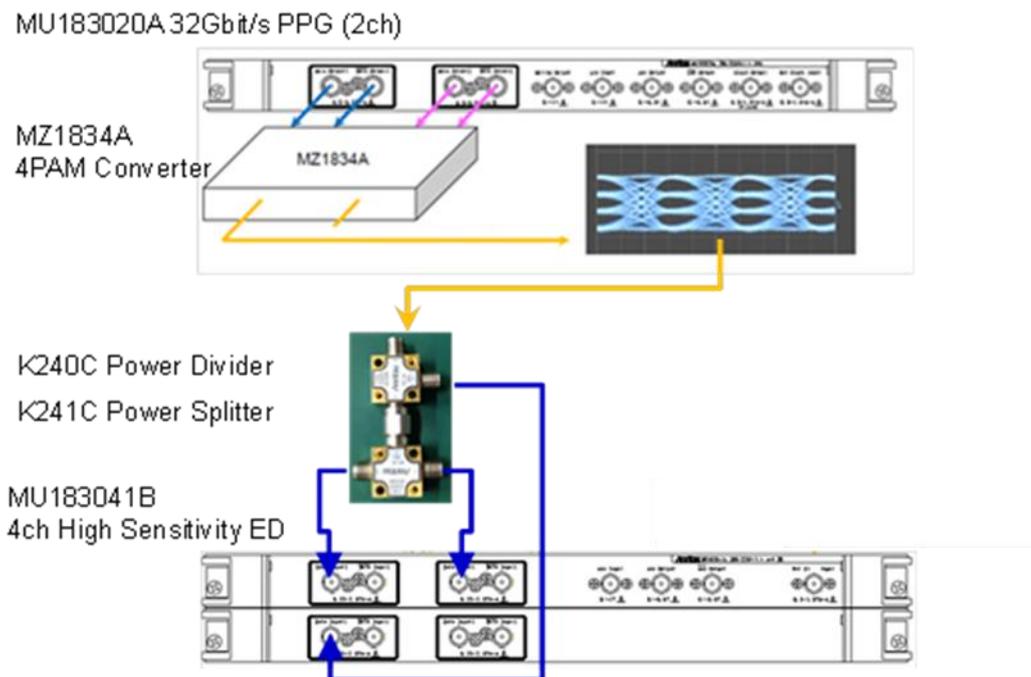


Fig. 4.1.2 PAM4 Generation and Three Eye Simultaneous Measurement System

The following describes the Three Eye serial measurement system (Fig. 4.1.3).

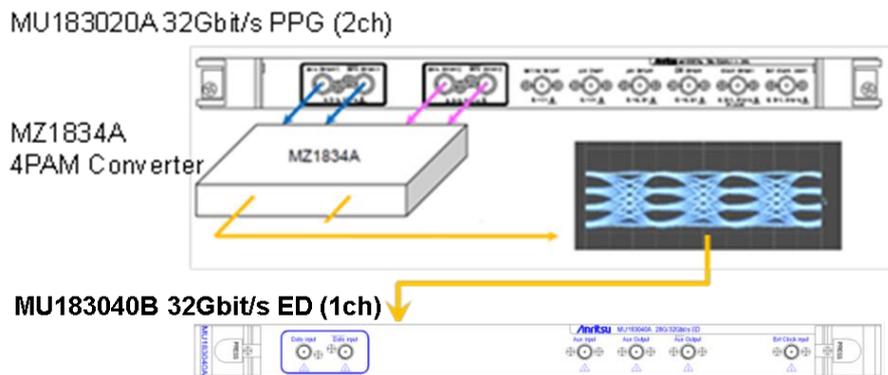


Fig. 4.1.3 PAM4 Generation and Three Eye serial Measurement System

The PAM4 signal generation side is the same as described previously. Since the measurement side is measured stepwise one Eye at a time, a 1CH ED can be used instead of using the previously described 4CH ED. Obviously, in this case, all bits of the signal received by the ED cannot be measured in real-time, but the trend in the signal quality can be found by measuring each of the three Eyes in turn. When using Clock Recovery with the Three Eye serial measurement system, a 2CH ED is used instead of a 1CH ED. In the same way as using a 4CH ED, set the PAM4 Middle Eye threshold at 1CH and perform BER measurement at 2CH. In this case, the PAM4 signal can be split by a power divider before input to the ED, or the Data side can be connected to 1CH and the XData side can be connected to 2CH. Since the measurement application (Fig. 4.1.4) for both PAM4 Three Eye simultaneous and serial measurement is installed in the MP1800A, Anritsu's measurement solution matches every customer configuration.

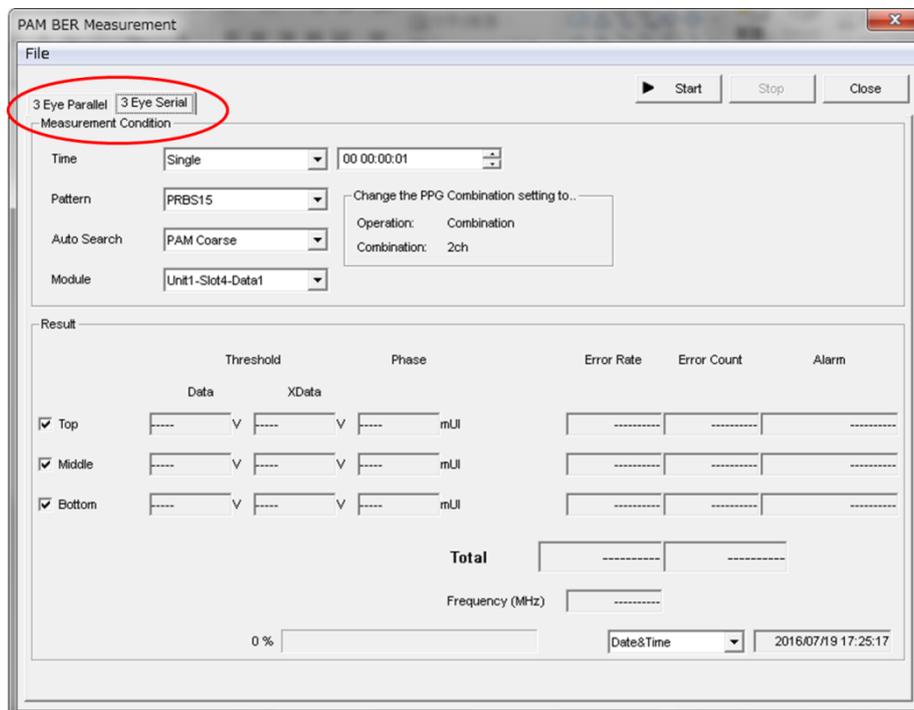


Fig. 4.1.4 Dual PAM4 Measurement Application

4.1.1 PPG Settings for 32 Gbaud PAM

To minimize the correlation between PPG1 and PPG2, the PRBS pattern period is moved alternately by half by setting to [2ch Combination].

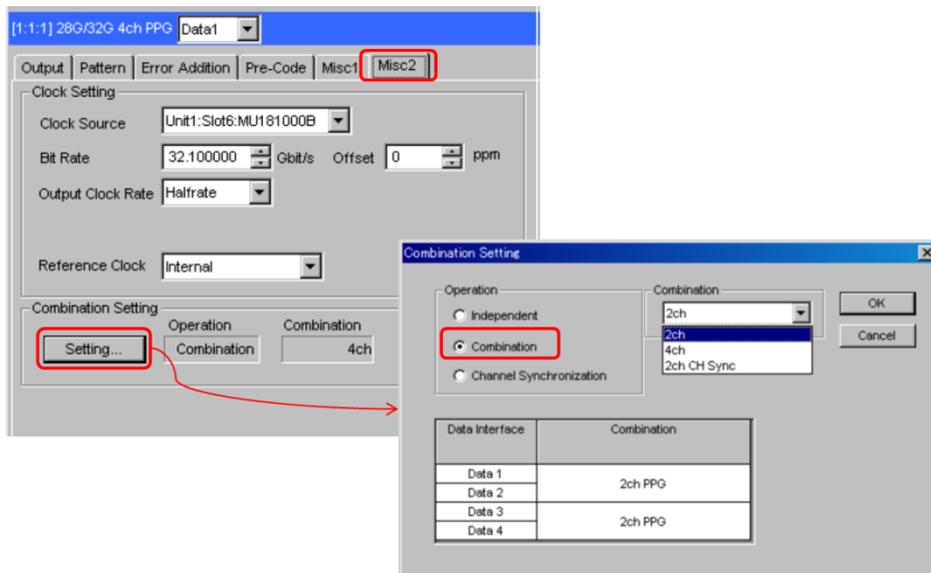


Fig. 4.1.1.1 2CH Combination Setting

- 1) As shown in Fig. 4.1.1.1, press the [Setting...] button at the [Misc2] tab of the PPG setting screen and select [Combination] at the [Operation] field in the Combination Setting screen.
- 2) When using the MU183021A 4CH PPG instead of the MU183020A, set [2ch] in the [Combination] field.
- 3) As shown in Fig. 4.1.1.2, select [Test Pattern] at the [Pattern] tab in the PPG setting screen and choose PRBS. Select [2⁷-1] at [Length].

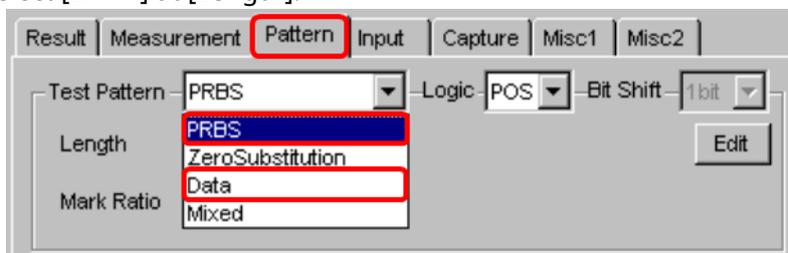


Fig. 4.1.1.2 Pattern Setting

- 4) Start the PAM Control Software and set Amplitude 1, 2, 3.
- 5) Use a sampling oscilloscope to monitor the PAM4 waveform.
- 6) If skew is observed in the PAM4 waveform, adjust the PPG Delay to minimize the skew.

4.1.2 ED Settings for 32 Gbaud PAM

As described in section 3, since the patterns at the ED side for Threshold 1 and Threshold 3 require changing from the usual PRBS pattern, instead of using a PRBS pattern, a User Programmable pattern is used.

As an example, this explains setting the two PPG patterns to PRBS7. Figure 4.1.2.1 shows the signal levels when the PAM4 PPG2 amplitude is twice that of PPG1. In this case, the signal is split into three for the three Thresholds measured by three EDs. Since Threshold 2 is the pattern of PPG2, in this case it is PRBS7. At Threshold 1, the bit where the PAM4 signal level is 3 is set as the "H" level, and the other bits are set as the "L" level. At Threshold 3, the bits where the PAM4 signal level is 0 are set as "L" level and the other bits as set as "H" level.

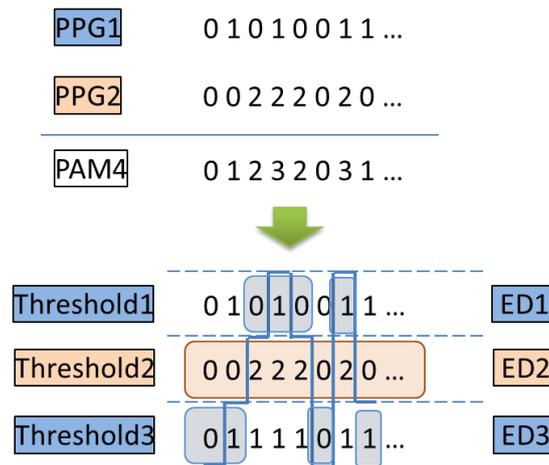


Fig. 4.1.2.1 PAM4 Signal ED Pattern

- 1) The pattern used for PAM4 testing is saved in the folder in the following path in the MP1800A.
<C:\¥Anritsu¥MT1800A¥Pattern Files¥PAM_Pattern>
An example for PRBS7 is described below.
- 2) As shown in Fig. 4.1.2.2, select [Test Pattern] at the [Pattern] tab in the ED setting screen.
- 3) Select [Data] for ED1 used for Threshold 1. This setting supports User Programmable patterns. Then, load the PN7_upper_bin.txt file.
- 4) Select [PRBS] for ED2 used for Threshold 2; select [2^7-1] at Length.
- 5) Select [Data] for ED3 used for Threshold 3. Then, load the PN7_lower_bin.txt file.

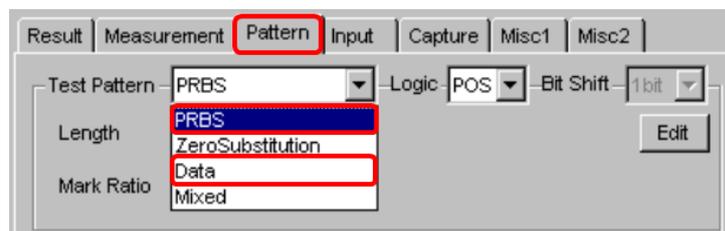


Fig. 4.1.2.2 ED Pattern Settings

The data pattern described above is already masked bits that should be excluded and can be used for accurate measurement.

This section describes methods for masking bits that should be excluded from the target measurement. Bits to be excluded for Threshold 1 are bits with the same timing as 0 in Threshold 2. For Threshold 3, bits for exclusion are bits with the same timing as 2 in Threshold 2. Parts that are not shaded across Threshold 2 and Threshold 3 in Fig. 4.1.2.1 are bits to be excluded from measurement.

- 6) The Pattern Editor is displayed by pressing [Data] – [Edit] at the [Pattern] tab (Fig. 4.1.2.3).
- 7) Select [BIN] at the [Format] item to display the measurement pattern in binary at the bottom of the Pattern Editor display.
- 8) Put a checkmark in [Block Window].
- 9) When bits to be excluded from measurement are selected, the selected bits are highlighted in blue. Blue-highlighted bits are excluded from measurement and are not included in Error totals.
- 10) After completing the mask settings, press the [OK] button to save the edit.

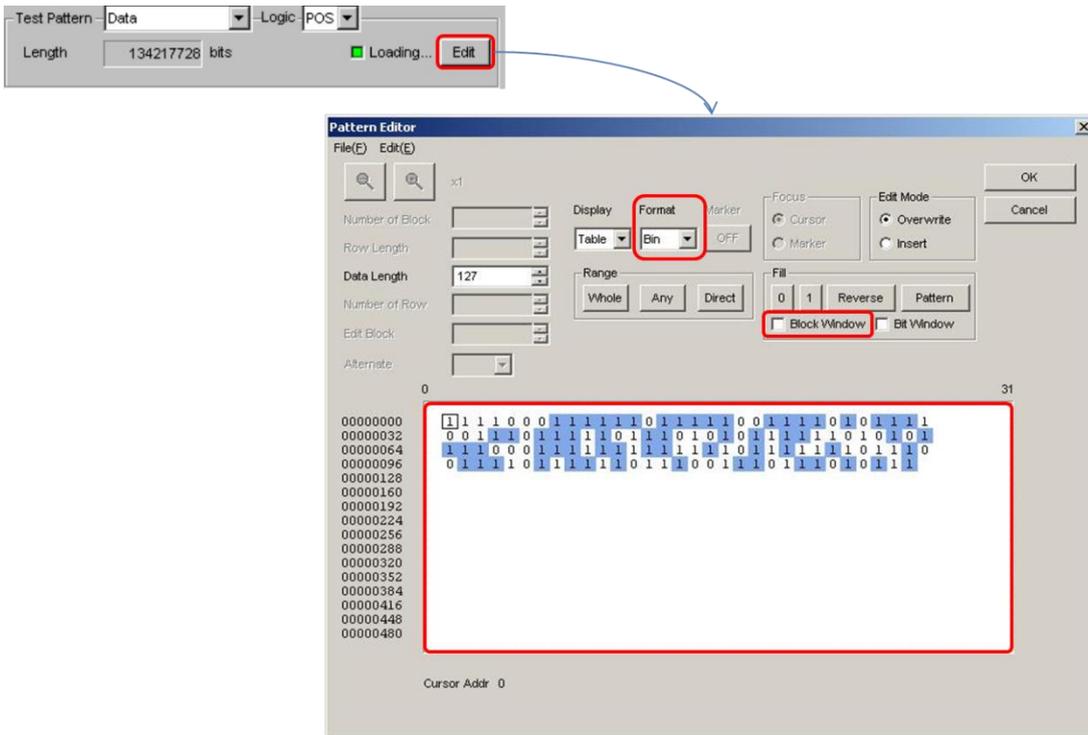


Fig. 4.1.2.3 Pattern Editor Mask Setting

11) Enable the mask function for the EDs for Threshold 1 and Threshold 3 by setting [Block Window] to [ON] as shown in Fig. 4.1.2.4.

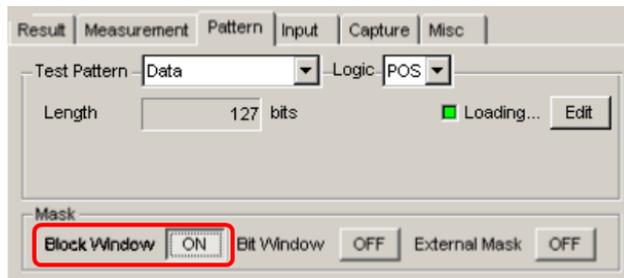


Fig. 4.1.2.4 Enabling Block Window Function

12) Set the ED input.

There are no special settings at single-ended measurement, but at PAM4 differential measurement, set Input Condition to Differential 50 Ohm – Independent at the [ED Input] tab. Since the Top Eye and Bottom Eye patterns are different with a PAM4 signal, when measuring the Top/Bottom Eye at Differential, it is necessary to reverse the Threshold Level at Data and XData. In other words, when measuring the Top Eye, the Threshold for the Data side is the Top Eye Threshold, but the Threshold for the XData side must be set to the Bottom Eye Threshold.

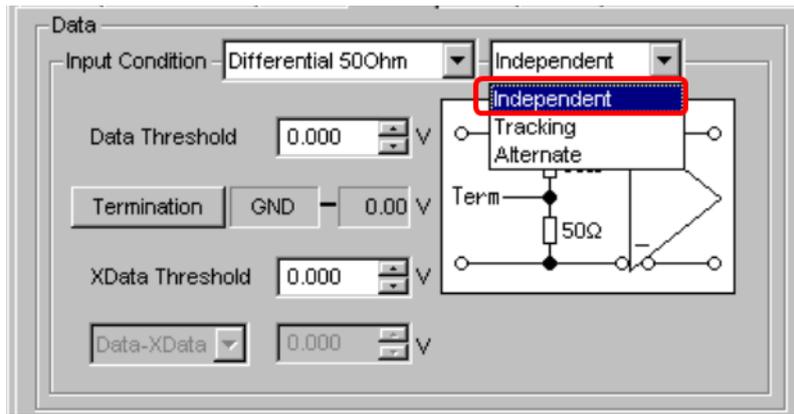


Fig. 4.1.2.5 ED Input Setting

13) The above procedure completes the PPG and ED settings and the PAM BER can be measured by adjusting the Threshold for each target ED.

As shown in Fig. 4.1.4, there are two methods for measuring PAM4 BER using the MP1800A. When using either one 4CH ED or two 2CH EDs, the ED for measuring each of the Top, Middle, and Bottom Eye is specified as shown in Fig. 4.1.4.

When using a 1CH ED, the Top, Middle, and Bottom Eye is measured serially as shown in Fig. 4.1.2.6, and the Total BER measurement result is displayed. Since the BER is measured sequentially using a 1CH ED, the measurement result does not measure all bits without exception. It displays the BER essentials as a probability.

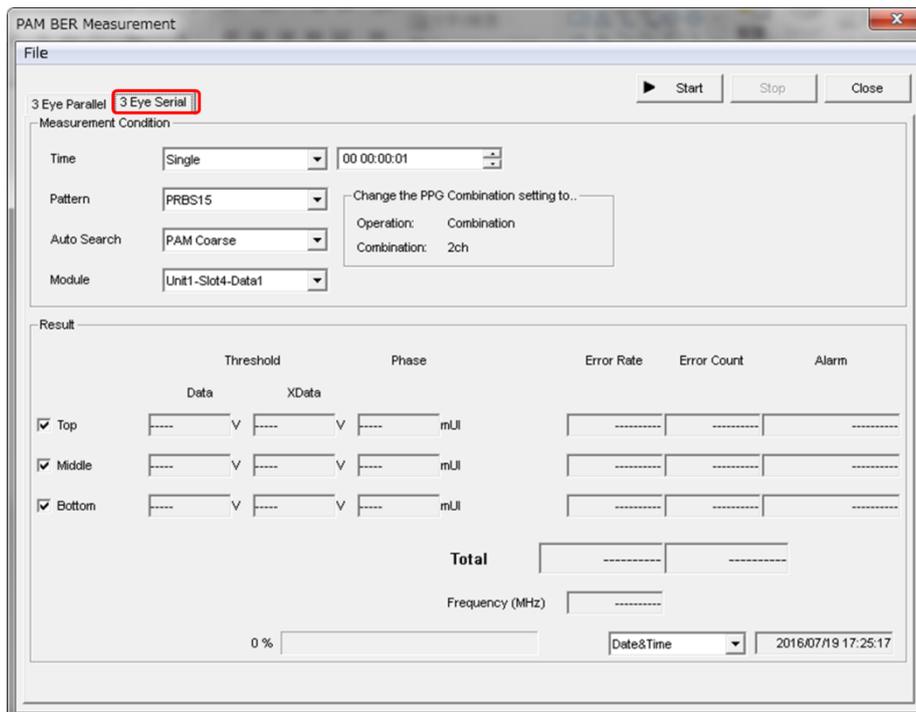


Fig. 4.1.2.6 Sequential PAM4 Measurement using 1CH ED

4.1.3 32 Gbaud PAM4 Patterns

PAM patterns with preset mask data as described in section 4.1.2 are saved in the following folder saved in the MP1800A main frame and can be used by customers without needing to edit mask data.

<C:\¥Anritsu¥MP1800A¥Pattern Files¥PAM_Pattern>

Table 4.1.3.1 lists and explains the PAM4 measurement patterns saved in the MP1800A.

Table 4.1.3.1 Description of PAM4 Patterns

Pattern name	Description
PRBS7, 9, 10, 11, 15, 20	Patterns generated by two PPGs and combined using PAM4 Converter
PRBS13Q, PRQS10	Patterns generated by same circuit as PRBS with same randomness as PRBS. Defined as PAM4 test patterns because the circuit can be expanded by PAM4 PRQS means Pseudo Random Quaternary Sequence. PRBS string has length of 2^n-1 while PRQS string has length of 4^n-1 . Patterns generated by same circuit as PRBS with same randomness as PRBS Defined as PAM4 test patterns because the circuit can be expanded by PAM4 PRQS means Pseudo Random Quaternary Sequence PRBS string has length of 2^n-1 while PRQS string has length of 4^n-1 .
Gray PRBS13Q	Pattern used for evaluating transmitter output and receiver input amplitude, Eye height, Eye width, and VEC performance using oscilloscope as defined by CEI-56G-VSR-PAM4. Pattern length (8191 bits) can be calibrated by oscilloscope and has high-order randomness. However, since PAM4 signal expresses 4 levels as pairs of 2 bits, sometimes 2-bit changes such as 01 -> 10 wrongly detected as change in 1 level. To suppress this detection error, Gray code (00 -> 00, 01 -> 01, 10 -> 11, 11 -> 10) used at Tx side and Opposite Gray Decode used at Rx side.
SSPR	Abbreviation for Short Stress Pattern Random with length of 32,762 bits defined by CEI 3.1 and with pattern length equivalent to PRBS15 and used as PAM4 evaluation pattern due to high stressability at Wander screen test.
JP03A	Pattern string of contiguous "03030..." used for transmitter Rj evaluation.
JP03B	Pattern string of 15 contiguous "03" followed by 16 contiguous "30" used for transmitter Even-Odd evaluations.
Square	Pattern string of 3333333300000000 used for OMA evaluation of optical interfaces.

4.2. 64 Gbaud PAM4 Solution

Table 4.2.1 lists the instruments used as the 56/64 Gbaud PAM4 Solution.

Table 4.2.1 Instrument Configuration for 64 Gbaud PAM4 Solution

Model Number	Model Name	Required Option	Note	Qty.
MP1800A	Main Frame	002, 015, 032		1
MU181000B	4port Synthesizer			1
MU183020A	PPG (2ch)	022, 031		2
MU183040B	ED (2ch)	020	High Sensitivity 10 mV (eye height)	1
MP1862A	56G/64Gbit/s DEMUX		Guaranteed up to 56Gbps with PRBS7 and PRBS15	1
G0374A	64Gbaud PAM4 DAC		Works up to 64Gbaud PAM4 / NRZ.	1
J1612A	Coaxial Cable 0.8m		K(m)-K(m) for data, Skew < 3ps.	6
J1661A	Coaxial Cable 1.3m		K(m)-K(m) for clock	3

These configurations do not describe the cables required for connection with the DUT.

Figure 4.2.1 shows the setup for the 56/64 Gbaud PAM4 Solution. Two 32G 2CH PPG modules for the MP1800A connect four Data signals to the G0374A 64 Gbaud PAM4 DAC to generate PAM4 and NRZ signals from 4.8 to 64 Gbaud. The four J1612A cables connecting the PPG Data outputs and the G0374A Data inputs assure a skew difference of less than 3 ps. If cables with a large skew are used, the phase margin of the G0374A input section is reduced, which increases the possibility of errors at the G0374A Data output. Additionally, although cables handling high-frequency signals have specified skew and frequency characteristics at purchase, bending during use and impression of high mechanical pressure can cause subsequent changes in the cable rating, so handle cables carefully to assure specifications

are satisfied.

Connecting the MP1862A with the MP1800A 32G 2CH ED at the Rx side supports PRBS15 BER measurements up to 56 Gbaud. Additionally, the Anritsu solution also supports PRBS7 and PRBS15 patterns for measurement of PAM4 signals generated by the G0374A at the MP1862A.

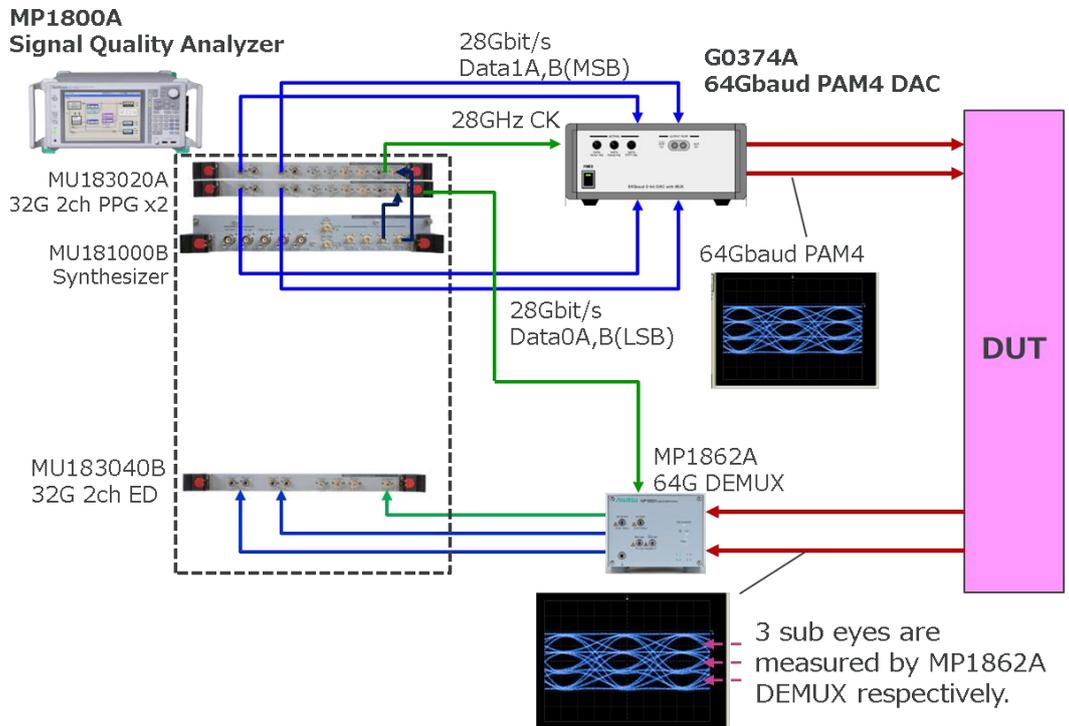


Fig. 4.2.1 56/64 Gbaud PAM4 Solution

4.2.1 Tx Settings for 64 Gbaud PAM

The PPG settings are made first. Since a 4CH PPG is connected to the G0374A, these 4CH are set at the same time. Press [Setting...] at the PPG [Misc2] tab to display the Combination Setting dialog and set [Operation] at the top left to [Combination] and select 64Gx2ch at the right side from the [Combination] settings.

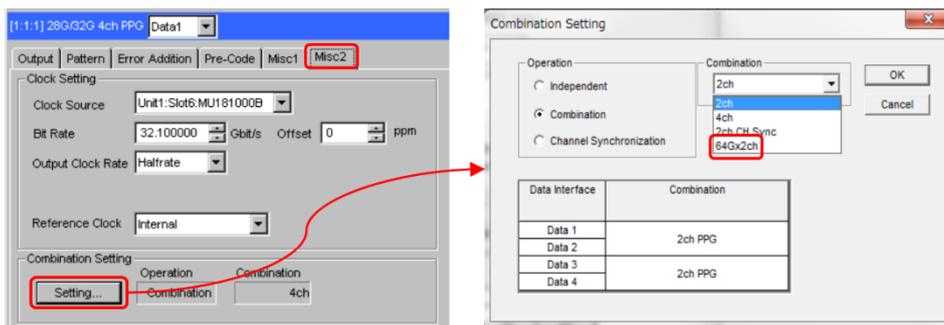


Fig. 4.2.1.1 PPG Combination Settings

Since this setting changes the output timing of the two 2CH PPGs alternately, it minimizes any correlation between the Data outputs when generating 64 Gbaud PAM4.

Next, set [Output Clock Rate] at the PPG [Misc2] tab to [Full Rate]. Then, set the PPG Data output amplitude for all 4CH to [1.0 Vpp] and the offset to Vth 0 V. Since the amplitude and offset must be set at each of the four channels, all four settings can be performed easily at once using the [Grouping Setting] at the PPG [Misc2] tab as shown in Fig. 4.2.1.2.

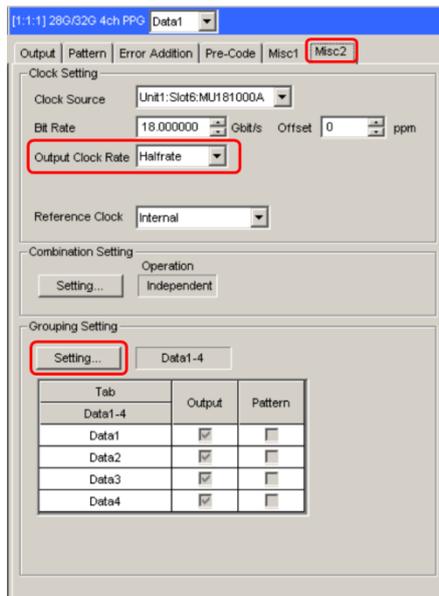


Fig. 4.2.1.2 Grouping Setting and Clock Output Settings

This completes the PPG settings. The following describes how to adjust the timing between the two PPGs and G0374A.

- A) Set the Test Pattern for both 2CH PPGs to [Data] with a pattern length of 16 bits and a pattern of 0001 1011 0010 0111.

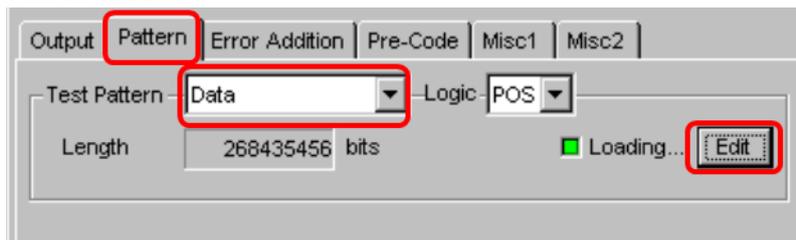


Fig. 4.2.1.3 Pattern Settings

- B) Set [Delay] for all channels of the PPGs to the same value. For example, set 0 mUI; the [Delay] value is set at the PPG [Output] Tab.

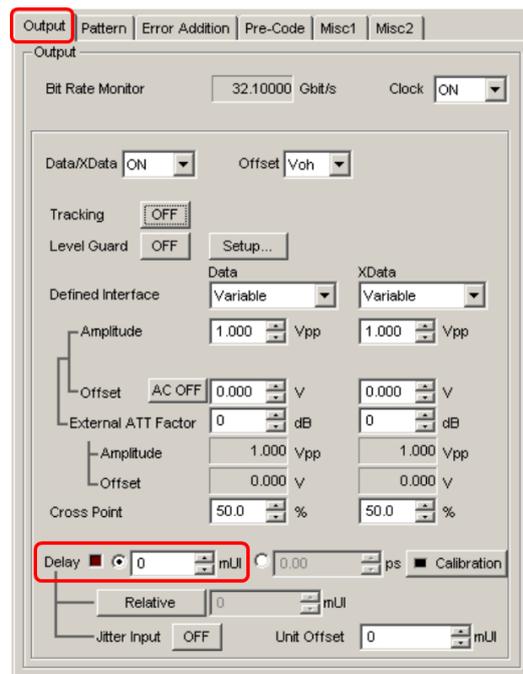


Fig. 4.2.1.4 PPG Delay Setting

- C) The result of generating a signal with the above-described settings in items A) and B) is monitored as shown in Fig. 4.2.1.5. If the monitored waveform is different from that in Fig. 4.2.1.5, adjust the PPG Delay for all channels in 100 mUI steps until the waveform appears the same as in the figure.

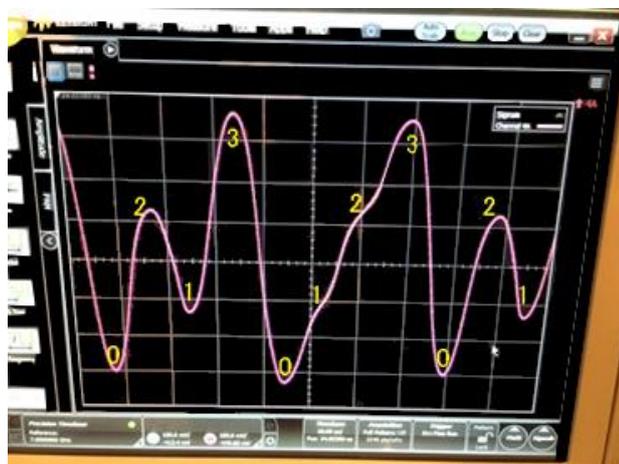


Fig. 4.2.1.5 01230213 Pattern

- D) Step C) completes the adjustment. With the waveform as shown in Fig. 4.2.1.5, set the PPG Pattern to PRBS15. In this condition, adjust the DATA DUTY Adj volume on the front panel of the G0734A so the size of the Eye amplitude for each bit is the same.

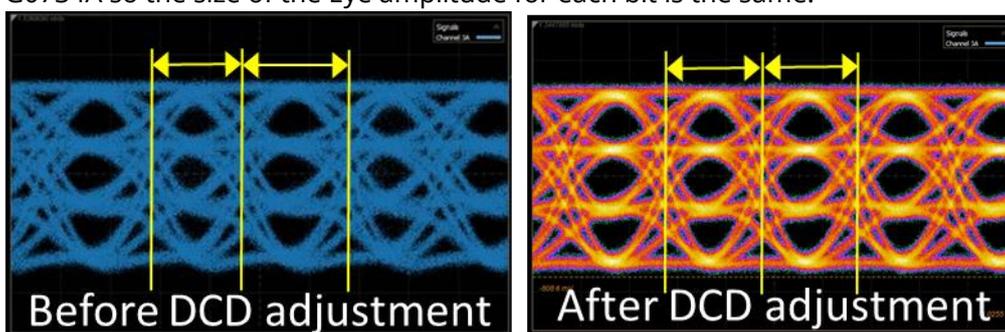


Fig. 4.2.1.6 DCD Adjustment

- E) Last, adjust the PAM4 output amplitude at the G0374A front panel to complete the waveform adjustment.

4.2.2 Rx Settings for 56 Gbaud PAM

The MP1862A 56/64 Gbit/s DEMUX can be used to perform the 53.1 Gbaud PAM4 BER measurements defined by IEEE and OIF. Setting a PRBS15 pattern using the MP1862A supports BER measurements up to 56 Gbaud PAM4.

Anritsu provides PRBS7 and PRBS15 patterns for BER measurements up to 56 Gbaud PAM4 using the MP1862A DEMUX. However, since a mask like that for 32 Gbaud PAM4 patterns is not set with these patterns, sometimes there may be more measurement errors than theoretically probable, depending on the signal because unnecessary parts are measured at the PAM4 Top Eye and Bottom Eye.

At PAM4 BER measurement, the MP1862A Threshold changes according to the measurement target Sub-EYE (Top/Middle/Bottom). When performing single-ended measurement of the Middle Eye, the best Threshold can be found using the Auto Search function.

5. Summary

This Application Note describes how to generate 32 and 64 Gbaud PAM signals for evaluation as well as BER measurement methods and measuring instrument requirements.

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