32 G/64 Gbaud Multi Channel PAM4 BERT
PAM4 PPG MU196020A
PAM4 ED MU196040A

Signal Quality Analyzer-R
MP1900A Series
Outline of MP1900A series PAM4 BERT

- Supports bit error rate measurements optimized for high-speed 400 GbE and next-generation 800 G interfaces.
- High-quality data output waveforms up to 64 Gbaud and high input sensitivity performance provide strong support for testing PAM4 device designs.
- The all-in-one jitter addition, clock recovery, Emphasis, PAM4 pattern editing, SER functions, etc.
- Offer an easily configured, high-reproducibility PAM4 measurement solution.

MP1900A PAM4 Target Applications
200/400/800 GbE, CEI-56G/112G, InfiniBand HDR, 64G Fibre Channel
MP1900A New PAM4 BERT Features

- All-in-one, high-reproducibility, easily configured test solution
- High-quality waveforms for more accurate measurement
- Easy, low-cost, future-proof expandability supporting high bit rates and multichannels
PAM4 PPG/ED Specifications

PAM4 PPG MU196020A

- Baud-rate: 2.4 Gbaud to 32.1 / 58.2 / 64.2 Gbaud (upper limit as option selections)
- Output amplitude: 0.14 Vp-p to 1.6 Vp-p (Differential)
- Emphasis: 4 Tap, ±20 dB (1 post/2 pre cursor)
- Intrinsic jitter(rms): 170 fs (typ., NRZ)
- Tr/Tf (20-80%): 8.5 ps (typ., NRZ)
- Multichannel synchronization*, FEC pattern generation* (*: Future support)

PAM4 ED MU196040A

- Baud-rate: 2.4 Gbaud to 32.1 Gbaud
- Input amplitude (maximum): 1.0 Vp-p (NRZ, PAM4)
- Input sensitivity: 23 mV (typ., Eye Height)
- Built-in Clock Recovery: 25.5 G to 32.1 Gbaud
- Analog bandwidth: > 40 GHz (nominal)
- SER measurement, logic error analysis by “Diagnostics Mode”
All-in-One PAM4 BERT Solution

Easy to use and configure all-in-one solution with high reproducibility, helping cut test times.

- SER Evaluation
- ED w/ Built-in Clock Recovery
- High Input Sensitivity, Supports <E-12 Error Measurement
- No External box, Compact Module w/ Built-in PAM4 Functions
- High-Quality 64G PAM4 Waveforms with Variable Emphasis/Linearity Functions
High-Quality Waveform PAM4 PPG MU196020A

Best-in-class waveform quality with low Intrinsic Jitter (typ. 170 fs (rms)) and fast Tr/Tf (typ. 8.5 ps) for more accurate evaluation of actual DUT performance.

64.2 Gbaud
53.125 Gbaud
26.5625 Gbaud

Differential 1.4 Vp-p, PRBS13Q pattern, J1789A 40 cm cable + 70 GHz Scope
Multichannel Support and Expandability

One MP1900A PPG supports up to 4ch* for 400 GbE (53 Gbaud x 4 Lanes), and Over 400 G evaluations, helping cut future support upgrade costs.

(*: Future support)

4-Lane DUT (Driver + E/O) Measurement Example
PAM4 PPG Functions and Performance
PAM4/NRZ Data Output

Supports next-generation Over 50 Gbaud applications, such as 400 GbE, CEI-112G, etc.

53.125 Gbaud PAM4, PRBS 15

58 Gbaud NRZ, PRBS 15

58 Gbaud PAM4, PRBS 15
Easy PAM4 Level Control

Control Baud Rate, Level, Offset, Half Period Jitter, and Delay from One Screen.

- PAM4 Total Amplitude Setting
- Independent PAM4 3EYE Amplitude Control with Voltage and % Values
- Easy return to equal level using [Even] button

Level Control Reference Waveform
Linearity and Emphasis controls

Supports TOSA device evaluations and stressed input tests using various channel insertion losses.

MU196020A
PAM4 PPG

53G, Post1 Emphasis control

53G, Linearity control

53G, Pre1 Emphasis control
PAM4 Test Patterns (1/2)

Support PAM4 test patterns specified by 200 and 400 GbE standards.

<table>
<thead>
<tr>
<th>Supported Test Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CEI</strong></td>
</tr>
<tr>
<td>QPRBS13-CEI, QPRBS31-CEI</td>
</tr>
<tr>
<td><strong>IEEE</strong></td>
</tr>
<tr>
<td>PRBS13Q, QPRBS13, PRBS31Q, SSPRQ, JP03A, JP3B, Transmitter Linearity, Square Wave</td>
</tr>
<tr>
<td><strong>InfiniBand</strong></td>
</tr>
<tr>
<td>PRBS13Q(InfiniBand), PRBS23Q, PRBS31Q(InfiniBand)</td>
</tr>
<tr>
<td><strong>Fibre Channel</strong></td>
</tr>
<tr>
<td>PRBS31Q(Fibre Channel)</td>
</tr>
<tr>
<td><strong>General Purpose</strong></td>
</tr>
<tr>
<td>PRBS7, 9, 10, 11, 13, 15, 20, 23, 31, Data (User defined) 4 to 256 M Symbol</td>
</tr>
</tbody>
</table>

Edit Data pattern using PAM4 symbol 0, 1, 2, and 3 values.
PAM4 Test Patterns (2/2)

- BER measurement for different pattern generation methods depending on DSPs
- Efficient detection of pattern generation circuit differences as well as logic errors, such as inverted logic and bit skew

Pattern Generation

MSB and LSB Inverted Logic (before/after Gray Coding)

Gray Coding

1/(1+D) Mod4 Pre-Coding

Set bit skew between MSB and LSB
PAM4 Error Insertion Function

With PAM4, not only do errors occur at single level changes, there are also cases where double level changes occur due to MSB errors. Using the [Error Addition] tab to insert errors in each of these cases helps confirm communications and inspection of error results.

- **LSB Error Insertion**
  - Level 0 to 1
    - 00 → 01
  - Level 1 to 0
    - 01 → 00
  - Level 2 to 3
    - 10 → 11
  - Level 3 to 2
    - 11 → 10

- **MSB Error Insertion**
  - Level 0 to 2
    - 00 → 10
  - Level 1 to 3
    - 01 → 11
  - Level 2 to 0
    - 10 → 00
  - Level 3 to 1
    - 11 → 01
Cable Settings for Monitoring

The loss of the 80 cm cable for connecting a separate DUT is corrected automatically by adjusting Emphasis.

Using 40 cm cable @53G

→ J1789A 40 cm cable best for evaluating this waveform

✓ Closed EYE opening with long cable (e.g., 80 cm cable)

↓ Can automatically calibrate settings for effect of 80 cm cable

Cable for data output setting: “J1790A 0.4 m”

Select J1790A cable setting

Cable for data output setting: “J1789A 0.4 m”

Using 80 cm cable @53G

→ J1789A 0.8 m Cable (Optional)
PAM4 ED Functions and Performance
**High Input-Sensitivity PAM4 ED MU196040A**

Supports $<E\cdot12$ error measurement using high input sensitivity and wideband (>40 GHz) functions even at input of 28 Gbaud and CEI-56G-VSR-PAM4 stress signal.

### Input Test Waveform Examples

![Input Test Waveform Examples](image)

### Calibrated input test signal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Test Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pk-Pk Amplitude</td>
<td>880 mVdiff (max.)</td>
<td>814 mVdiff</td>
</tr>
<tr>
<td>EH</td>
<td>32 mVdiff (min., at E-6)</td>
<td>32.2 mVdiff (at E-6)</td>
</tr>
<tr>
<td>EW</td>
<td>0.2 UI / 7.1 ps (min., at E-6)</td>
<td>4.1 ps (at E-6)</td>
</tr>
</tbody>
</table>
**Built-in Clock Recovery and PAM4 Decode Functions**

- Direct input signal measurement using built-in clock recovery eliminates external divider circuit
- Detailed unique separate MSB and LSB error analysis using PAM4 Decode function

Block diagram of PAM4 ED front-end:

- Data Input
- Clock Input
- PAM4 Decoder
- Variable Delay
- Clock Recovery
- Error Analysis

MSB and LSB outputs.
Error Analysis Function (1/2)

Measurement of both symbol errors (MU196040A-041) and bit errors is useful for specifying error causes by comparing both measurement results. In addition, pressing [Details] offers more detailed analysis by confirming results for 12 types of errors.

PAM4 bit error measurement results
Separate error-rate measurements for MSB and LSB
Simultaneous measurement of 12 error types
The Diagnostics Mode is useful for troubleshooting logic errors, such as inverted logic and MSB/LSB bit skew, etc. When these types of logic errors prevent synchronization, the cause can be determined using the separate MSB and LSB error results and the bit skew result between MSB and LSB.
Jitter Tolerance Measurement Function

The PAM4 Jitter Tolerance test is supported using just one unit. A measurement system to help cut measurement time is easily configured by combining the Jitter/Noise Addition function, built-in clock recovery function, and Jitter Tolerance MX183000A-PL001 software.
Appendix
### Typical configuration of 64 G PPG/32 G ED

<table>
<thead>
<tr>
<th>Model</th>
<th>Name</th>
<th>Option</th>
<th>Qty</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP1900A</td>
<td>Signal Quality Analyzer-R</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MU181000B</td>
<td>12.5GHz 4 port Synthesizer</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MU181500B</td>
<td>Jitter Modulation Source</td>
<td>-</td>
<td>1</td>
<td>For jitter injection</td>
</tr>
<tr>
<td>MU196020A</td>
<td>PAM4 PPG</td>
<td>003, 011, 030</td>
<td>1</td>
<td>With 64G, Emphasis, Data Delay options</td>
</tr>
<tr>
<td>MU196040A</td>
<td>PAM4 ED</td>
<td>001, 022, 041</td>
<td>1</td>
<td>With 32G, Clock recovery, SER options</td>
</tr>
</tbody>
</table>

### Ordering Information

<table>
<thead>
<tr>
<th>Model</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MU196020A</td>
<td>PAM4 PPG</td>
</tr>
<tr>
<td>MU196020A-001</td>
<td>32G baud</td>
</tr>
<tr>
<td>MU196020A-002</td>
<td>58G baud</td>
</tr>
<tr>
<td>MU196020A-003</td>
<td>64G baud</td>
</tr>
<tr>
<td>MU196020A-011</td>
<td>4Tap Emphasis</td>
</tr>
<tr>
<td>MU196020A-030</td>
<td>Data Delay</td>
</tr>
<tr>
<td>MU196040A</td>
<td>PAM4 ED</td>
</tr>
<tr>
<td>MU196040A-001</td>
<td>32.1G baud Decoder</td>
</tr>
<tr>
<td>MU196040A-022</td>
<td>25.5G to 32.1G baud Clock Recovery</td>
</tr>
<tr>
<td>MU196040A-041</td>
<td>SER Measurement</td>
</tr>
<tr>
<td>J1789A</td>
<td>Electrical Length Specified cable (0.4m, V connector)</td>
</tr>
<tr>
<td>J1790A</td>
<td>Electrical Length Specified cable (0.8m, V connector)</td>
</tr>
<tr>
<td>Item</td>
<td>Specification</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>2.4 to 32.1 Gbaud/58 Gbaud/64.2 Gbaud</td>
</tr>
<tr>
<td>Output Signal format</td>
<td>NRZ, PAM4</td>
</tr>
<tr>
<td>Number of Outputs</td>
<td>2 (Data, xData)</td>
</tr>
<tr>
<td>Output Amplitude</td>
<td>0.07 to 0.8 Vp-p (single output)</td>
</tr>
<tr>
<td></td>
<td>0.14 to 1.6 Vp-p (differential output)</td>
</tr>
<tr>
<td>Offset</td>
<td>–2.0–Eye Amplitude/2 to +3.3–Eye Amplitude/2 Vth</td>
</tr>
<tr>
<td>Tr/Tf (20% to 80%)</td>
<td>8.5 ps (typ.)</td>
</tr>
<tr>
<td>Intrinsic Jitter</td>
<td>170 fs rms (typ.)</td>
</tr>
<tr>
<td>Patterns</td>
<td>PRBS, Data(max. 268 Mbit(symbol)), PAM4 Pattern (PRBS13Q, PRBS31Q, SSPRQ, QPRBS13-CEI, QPRBS31-CEI), Gray Code/PAM4 Pre-Code</td>
</tr>
<tr>
<td>Emphasis Tap Count</td>
<td>4 Tap</td>
</tr>
<tr>
<td>Emphasis Gain</td>
<td>–20 to +20 dB</td>
</tr>
<tr>
<td>Jitter Addition Function</td>
<td>SJ, RJ, BUJ, SSC</td>
</tr>
<tr>
<td>Noise Addition Function</td>
<td>CMI, DMI, White Noise (Option)</td>
</tr>
<tr>
<td>Connector</td>
<td>V (f)</td>
</tr>
</tbody>
</table>
# PAM4 ED MU196040A Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baud rate</td>
<td>2.4 to 32.1 Gbaud</td>
<td></td>
</tr>
<tr>
<td>Input Signal Method</td>
<td>NRZ, PAM4</td>
<td></td>
</tr>
<tr>
<td>Number of Inputs</td>
<td>2 (Data, xData)</td>
<td></td>
</tr>
<tr>
<td>Input Amplitude (max.)</td>
<td>1.0 Vp-p</td>
<td></td>
</tr>
<tr>
<td>Input Sensitivity</td>
<td>23 mV (EH, typ.)</td>
<td>Height of each PAM4 Eye</td>
</tr>
<tr>
<td>Stressed Margin</td>
<td>BER &lt; 1 E-12</td>
<td>When inputting minimum eye signal defined in CEI-56G-VSR</td>
</tr>
<tr>
<td>Analog Band</td>
<td>&gt;40 GHz (nominal)</td>
<td></td>
</tr>
<tr>
<td>Clock Recovery Operation Range</td>
<td>25.5 to 32.1 Gbaud</td>
<td>Option</td>
</tr>
<tr>
<td>BER/SER Measurement</td>
<td>Total BER, MSB/LSB BER, SER (option)</td>
<td></td>
</tr>
<tr>
<td>Patterns</td>
<td>PRBS, Data(max. 268 Mbit(symbol)), PAM4 Pattern</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(PRBS13Q, PRBS31Q, SSPRQ, QPRBS13-CEI, QPRBS31-CEI,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gray Code/PAM4 Pre-Code</td>
<td></td>
</tr>
<tr>
<td>Connector</td>
<td>K (f)</td>
<td></td>
</tr>
</tbody>
</table>
PAM4 Test Patterns

**PRBS13Q, PRBS31Q, SSPRQ:**
PAM4 patterns defined by IEEE802.3bs, 802.3cd 200 GbE, and 400 GbE standards

**QPRBS13-CEI:**
Pattern for Tx output measurement and Rx input calibration defined by CEI-56G PAM4 standard

**JP03A:**
“0303...” pattern string for evaluating transmitter RJ

**JP03B:**
Pattern (shown below) of 62 symbols composed of string of 15 contiguous “03” followed by 16 contiguous “30” for evaluating transmitter Even-Odd jitter

```
03030303030303030303030303030303
30303030303030303030303030303030
```

**Square:**
“3333333300000000” pattern string for OMA evaluation of optical interfaces (OMA: Optical Modulation Amplitude)

**Transmitter Linearity Test Pattern:**
Pattern of 160 symbols with following sequence of 10 PAM4 symbols repeated in 16UI lengths

\{(0, 1, 2, 3, 0, 3, 0, 3, 2, 1)\}

The newest specification for the Linearity Test uses a PRBS13Q pattern.

\[
R_{LM} = \min((3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)) \\
V_{mid} = \frac{(V_0 + V_3)}{2}, \quad ES1 = \frac{(V_1 - V_{mid})}{(V_0 - V_{mid})}, \quad ES2 = \frac{(V_2 - V_{mid})}{(V_3 - V_{mid})}
\]

**Gray-xxxx:**
PAM4 signals use four levels to express 2-bit pairs, but sometimes a 2-bit change such as 01→10 may be detected incorrectly for one level. To prevent this, a Gray code (00→00, 01→01, 10→11, 11→10) is used as the pattern at the Tx side.