SHF
Signal Generation & Analysis

NRZ, PAM Pattern and Arbitrary Waveform Generation

SHF has always been pioneering the market for high-speed Bit Pattern Generators (BPGs) or Pulse Pattern Generators (PPGs). Now, with PAM4 being the main stream of interest, SHF's remote head architecture provides the most flexible approach for 400G, 800G and 1.6T applications.


SHF 12105 A BPG with remote heads

The basis instrument for data generation is the BPG. Simply by extending the BPG with a small, lightweight and field replaceable remote head, different line rates and modulation schemes can be achieved. This renders this approach most flexible and future proof as new remote heads released by SHF will continue to be a fitting extension.

A SHF BPG and a SHF DAC are not just two discrete modules connected together. The complementary software package unifies them to virtually one instrument.

From the vast number of configuration possibilities, a few are outlined in the table below.

Basis Model	Remote Head	Available Options
SHF 12105 A **Pattern Generator**	---	⊿ Up to 8 NRZ Channels ⊿ Up to 64 Gbps per channel ⊿ Built-in PRBS patterns and 8 Gbit user pattern per channel ⊿ High voltage options
	SHF C603 B **2:1 MUX**	⊿ Up to 4 NRZ Channels ⊿ Up to 128 Gbps per channel ⊿ Built-in PRBS patterns and 16 Gbit user pattern per channel
	SHF 614 C **6-Bit DAC**	⊿ Full AWG capabilities with 6-Bit vertical resolution ⊿ Up to 60 GSymbols/s e.g., 60 GBaud PAM4 (128. Gbps) ⊿ 8 GSymbols waveform memory ⊿ Example application: PAM4 with Pre-Emphasis and unequal eye openings.
	SHF C911 A **4-Bit DAC**	⊿ Up to 4 PAM4 or up to 2 PAM8 / PAM16 channels ⊿ Up to 64 GBaud PAM4 (128 Gbps) per channel ⊿ Built-in PRBS and PAM patterns (e.g., PRBS31Q) plus 8 Gbit user pattern per channel
	SHF 616 C **PAM-MUX**	⊿ Up to 2 PAM4 Channels ⊿ Up to 128 GBaud PAM4 (256 Gbps) per channel ⊿ Built-in PRBS and PAM patterns (e.g., PRBS31Q) plus 8 Gbit user pattern per channel

Often such signals are generated by classic AWGs, but for data signals our BPG approach has significant advantages as logical pattern generation techniques can be applied without utilizing a rather slow and small memory. The coding is done in hardware and thus parameters can be adjusted on the fly without waiting for the memory to be loaded. Very long patterns (e.g., PRBS 2^{31}-1 or PRBS31Q) can be generated instantly. Further, the remote heads can be placed very close to the DUT. The light weight makes it even possible to place them on a waver prober.
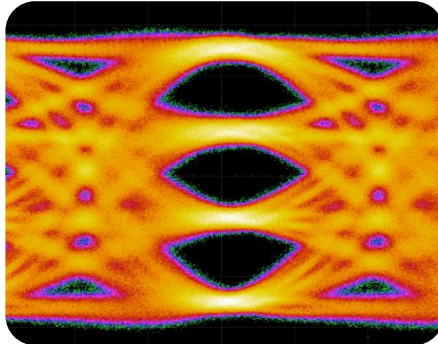
**100 GBaud (200 Gbps)
from a SHF 616 C**
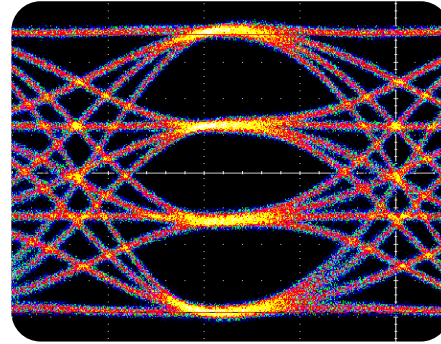
**50 GBaud (100 Gbps)
from a SHF C911 A DAC**

NRZ & PAM Error Analysis

The SHF 11104 A Error Analyzer (EA) or Error Detector (ED) is capable not only to perform BER measurements at binary but also at PAM4 signals. Via a 3-pass approach, the instrument performs an auto-search to determine the optimum timing and threshold of the three individual PAM4 eyes. During the actual measurement it successively samples all three eye openings, one at a time, and measures the three individual bit error ratios. In parallel to this 3-pass measurement the software calculates the total Bit Error Ratio (BER).

SHF 11104 A EA extended with a SHF 11220 A PAM-Sampler

The SHF 11104 A Error Analyzer as a single instrument is capable to perform such BER measurement. Extended with a remote head, the upper baud rate limit is raised.

Base Model	Remote Head	Available Options
SHF 11104 A **Error Analyzer**	---	⚠ Up to 64 Gbps NRZ per channel ⚠ Up to 32 GBaud PAM4 (64 Gbps) per channel
	SHF 11221 A 1:2 DEMUX	⚠ Up to 128 Gbps NRZ per channel
	SHF 11220 A PAM-Sampler	⚠ Up to 58 GBaud PAM4 (116 Gbps) per channel.

Adaptive Equalization

The EA with or without a remote head offers an excellent sensitivity to enable BER measurements of signals even with small eye openings. Still, in case the transmission path introduces significant signal distortion it may render BER measurements impossible. SHFs analog FIR equalizer module is intended to overcome this hurdle.

P/N	Description
SHF C683 A **Analog FIR Filter**	⚠ Bandwidth > 55 GHz (suitable for PAM4 signals from 20 to 70 GBaud) ⚠ 6 taps

The following pictures show 64 GBaud (128 Gbps) PAM4 signals measured with a high-speed sampling scope in its original state (e.g., degraded by a DUT) and improved by equalization through the SHF C683 A. After equalization, the signal eyes are opened up and absence of errors (BER < 10^{-11}) is verified.

The FIR filter is accompanied by the SHF-Optimizer software which

⚠   automates the tap calculation,

⚠   bases its calculation either on ideal inputs, imported signals or measurements directly acquired from a scope

⚠   previews the optimized and non-optimized eyes and frequency responses.
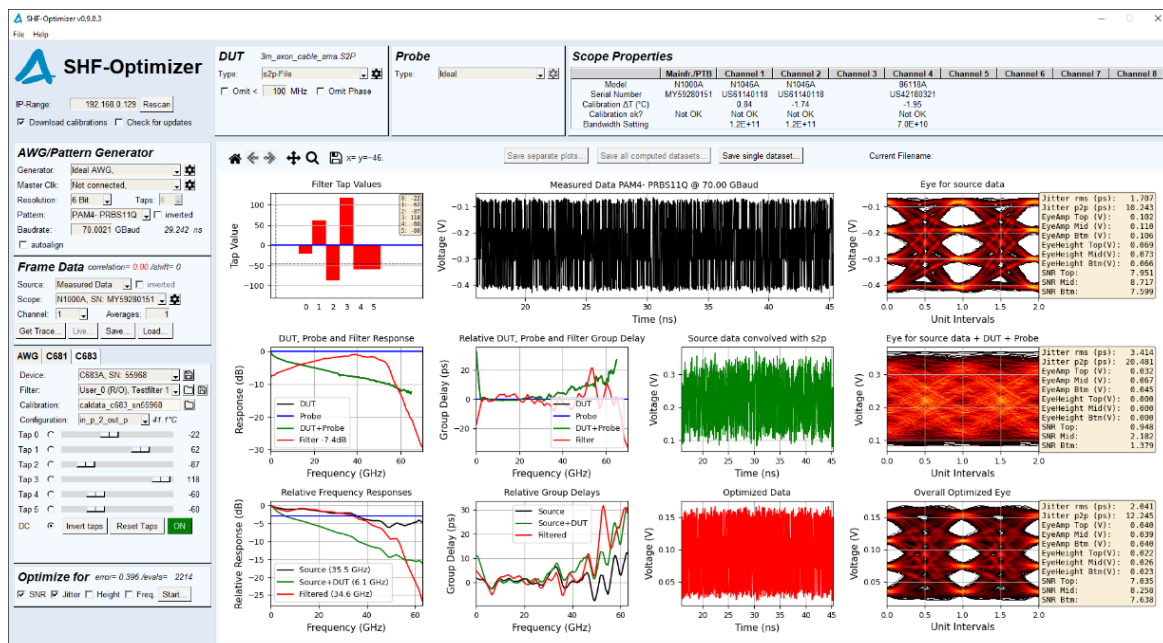
Synthesized Signal Generation

In digital high-speed test and measurement set ups with or without above outlines SHF BPGs and EAs, a perfect clock signal is crucial for the generation of low jitter reference test signals. A SHF Synthesized Signal Generator (Synthesizer) used as a clock source can operate over several decades of frequency.

P/N	Description
SHF 78124 A | 32 Synthesizer	◬ Output signals from 1… 32.8 GHz
SHF 78124 A | 64 Synthesizer	◬ Output signals from 1… 64.0 GHz

In contrast to other high-speed signal generators SHF synthesizers focus on the generation of CW signals only which enables us to offer the most cost-effective solutions in this frequency range. The high purity and fidelity could be achieved by waiving potentially unrequired components and capabilities (like e.g., signal modulation or complex signal sweeps).

32 GHz from a SHF 78124 A

In case other frequencies, more outputs or phase shifts are required, there is a huge variety of external modules to provide the signal exactly as needed in the setup:

◬ Clock Distributions,

◬ Phase Shifters,

◬ (Clock Signal) Amplifiers,

◬ Frequency Dividers & Multipliers.