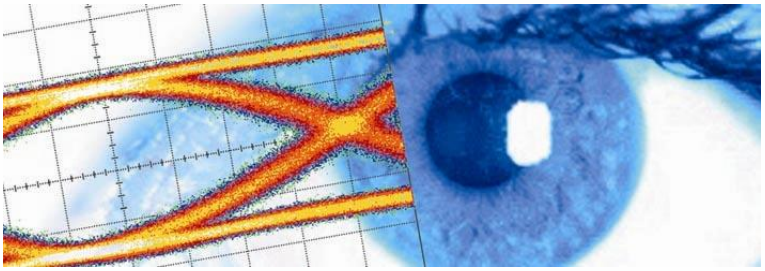
SHF BERT & DAC for NRZ, PAM4 and Arbitrary Waveform Generation



SHF has always been pioneering the market for high-speed Bit Pattern Generators (BPGs) / Pulse Pattern Generators (PPGs), and Error Analyzers (EAs) / Error Detectors (EDs). Now, with PAM4 being the main stream of interest, SHF is continuing to push the limits with its flexible remote head approach.

SHF's "one for all" BPG

The key instrument for the data generation is the SHF 12105 A Bit Pattern Generator (BPG) which can be configured in a variety of different channel configurations with a maximum capacity of 512 Gbps per instrument (8 channels, each up to 64 Gbps). Simply by extending this BPG with a small and lightweight remote head, other line rates and modulation schemes beyond 64 Gbps NRZ 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 to the SHF 12105 A.

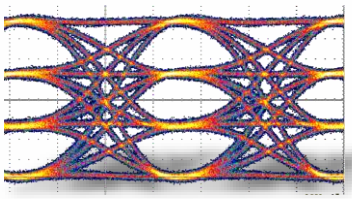
From the vast number of configuration possibilities, in this brochure we are focusing on a few key applications.

SHF 12105 A BPG with remote heads

4x PAM4 up to 60 GBaud (120 Gbps)

Feeding every two of the eight NRZ BPG channels into one of four DACs in two-bit mode generates four independent PAM4 data streams at the highest signal fidelity.

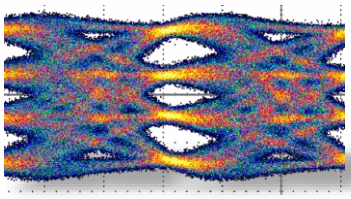
This active approach is much more robust than simple passive combining. Further, different to an AWG it samples precisely one single time per bit of the input data. Thus, the baud rate of the resulting PAM signal is as fast as the sample rate of the system.



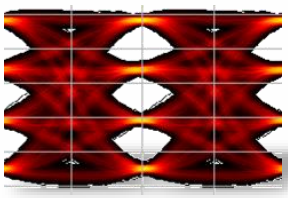
50 GBaud PAM4 from a SHF C911 A DAC

PAM4 up to 128 GBaud (256 Gbps)

The speed advantage of the SHF system can be seen most prominently by combining the SHF 616 C PAM-MUX with the BPG. This system supports data rates up to 128 GBaud (256 Gbps).



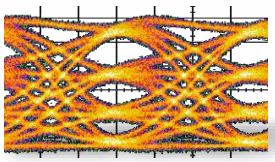
100 GBaud (200 Gbps)
on scope display



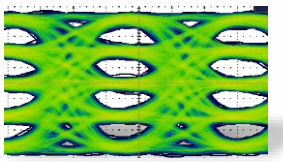
100 GBaud (200 Gbps)
post processed with a software-based FFE

PAM up to 60 GBaud (120 Gbps) with pre-emphasis

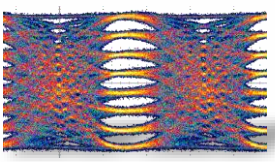
Feeding two channels into a DAC gives perfect and symmetric PAM4 (as above). Using more BPG channels and a DAC with higher number of bits, however, gives more flexibility and resolution. With our 6-Bit DAC SHF 614 C this flexibility can be used for example for pre-emphasis, unequal eye openings or different number of levels.



Unequal PAM
@ 60 GBaud (120 Gbps)

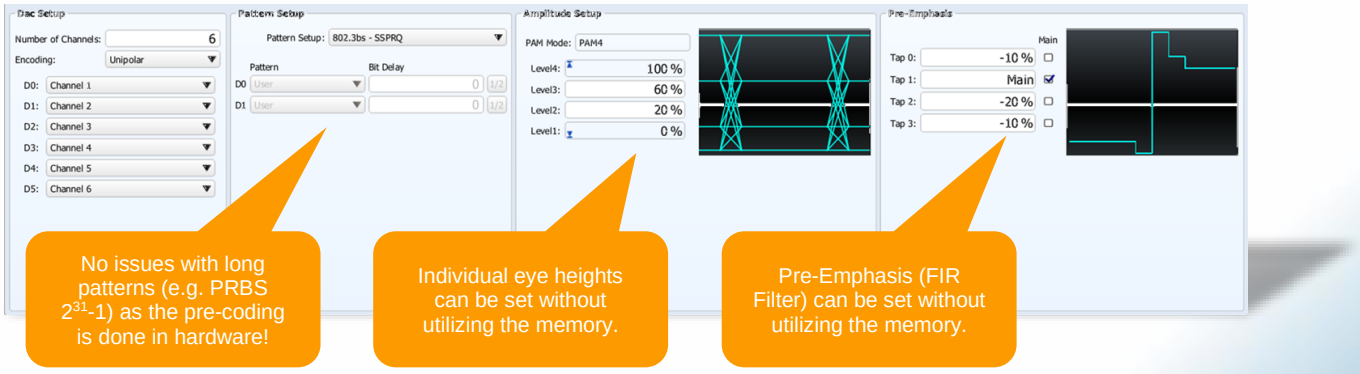


Odd PAM (here PAM-5)
@ 60 GBaud (120 Gbps)



PAM-8
@ 60 GBaud (120 Gbps)

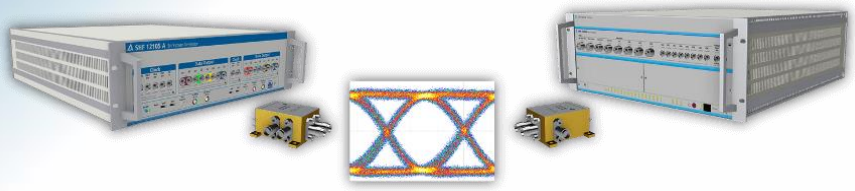
Often such signals are generated by classic AWGs, but for such data signals our BPG approach has significant advantages as logical pattern generation techniques can be applied without utilizing a rather slow upload and small memory size. The coding is done in hardware and thus parameters can be adjusted 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' without any memory-related limitations.



BPG GUI of the SCC for the logical PAM signal generation

NRZ up to 128 Gbps

In the same way a 2-Bit DAC is doubling the number of levels, the SHF C603 B multiplexer (MUX) is doubling the speed. This way up to four NRZ channels, each up to 128 Gbps can be generated.



120 Gbps signal generation and detection

Together with the fitting 120 Gbps demultiplexer, a full 120 Gbps bit error rate test system is realized. Configured as a SHF 11221 A the demultiplexer does provide the same measurement convenience as a 60 Gbps Error Analyzer as it features a computer controlled delay line for automated sampling point adjustments.

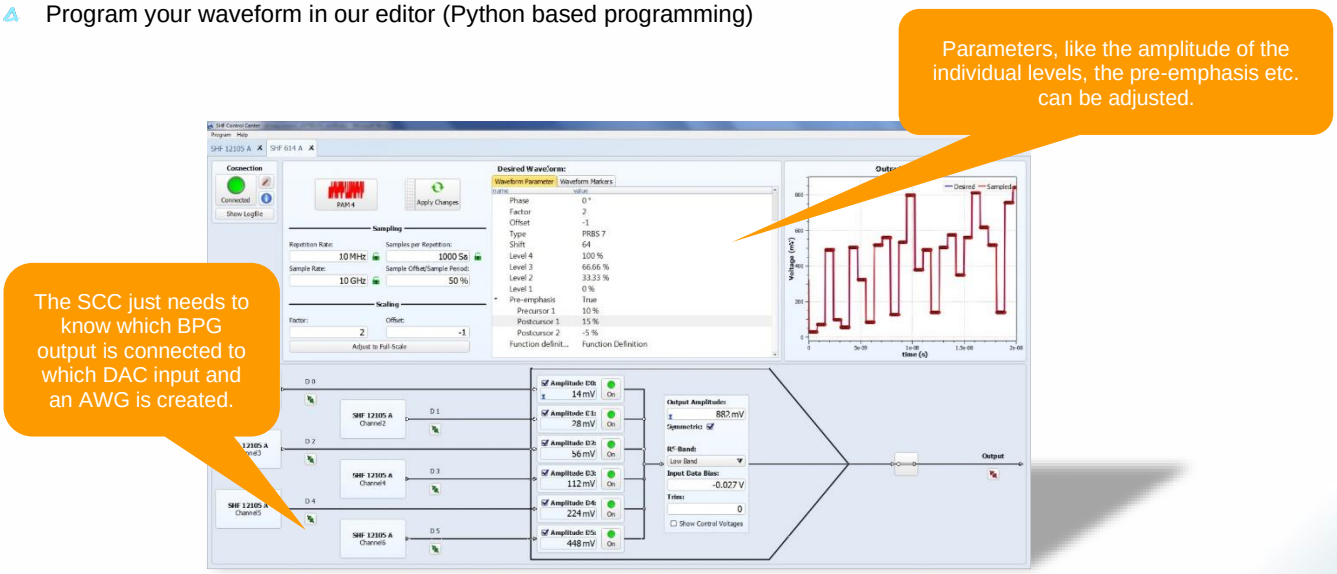
60 GSymbols/s AWG

With our SHF 12105 A BPG, one has full control of the patterns into the DAC (due to the huge memory and the channel synchronization). Therefore, our BPG-DAC combination also operates as a non-interleaved 60 GBaud Arbitrary Waveform Generator (AWG) with a remote head to preserve signal integrity close to the DUT.

Hardware-wise, the setup would be the same as introduced above (PAM up to 60 GBaud (120 Gbps) with pre-emphasis) just with the difference that we are now making use of the 8 GSa waveform memory of the SHF 12105 A in order to generate any other signal traces, including analog waveforms.

A SHF BPG and a SHF DAC are not just two discrete modules connected together. The complementary software package, the SHF Control Center (SCC) unifies them to virtually one instrument. As for a conventional AWG, there are various options to create the waveform:

- Load it from a file
- Select from our library & change the parameters (a PAM4 example is shown below)
- Use the graphical sequence editor
- Program your waveform in our editor (Python based programming)



DAC GUI of the SCC with the PAM4 library loaded

PAM4 Analyzer up to 58 GBaud (116 Gbps)

The SHF 11104 A Error Analyzer (EA) is capable not only to perform BER measurements at binary level, but also at PAM4 signals via a “3-pass” approach. With this approach, the instrument performs an auto-search to determine the optimum timing and threshold values of the three individual PAM4 eyes. During the actual measurement it successively samples all three eye openings of the 4-level signal, 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).

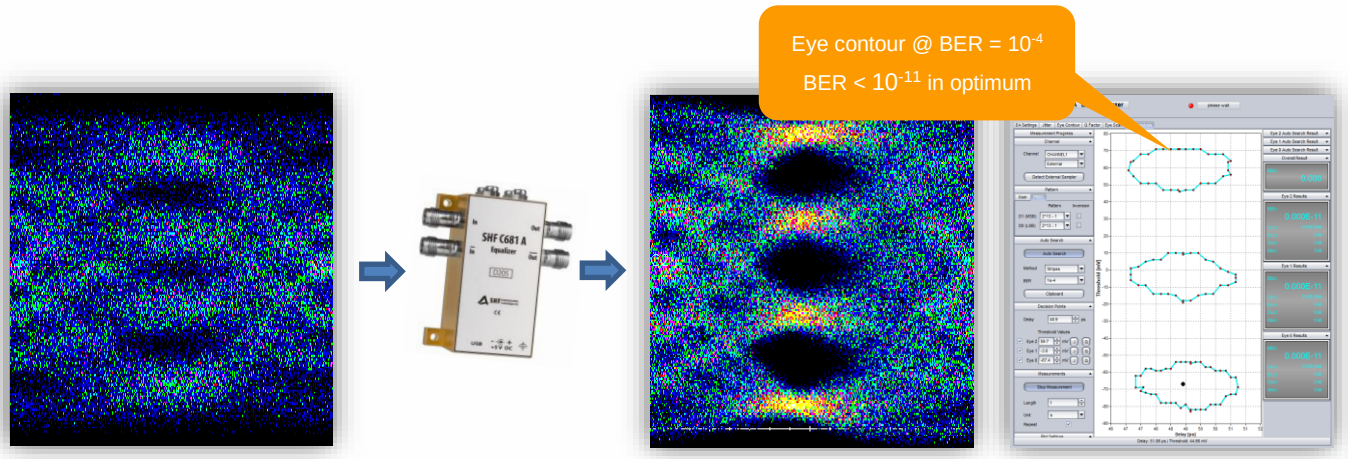
SHF 11104 A EA extended with a SHF 11220 A PAM-Sampler

The SHF 11104 A Error Analyzer as a single instrument is capable to perform this measurement for PAM4 signals up to 32 GBaud (64 Gbps). Extended with the SHF 11220 A PAM-Sampler, the upper baud rate limit is raised to 58 GBaud (116 Gbps).

Adaptive Equalization

The SHF 11104 A EA and the SHF 11220 A PAM4-Sampler combination offers excellent sensitivity to enable BER measurements of signals even with small eye openings. In a majority of test and measurements, however, the transmission path or the device under test (DUT) can introduce significant signal distortion and eye closure, rendering BER measurements impossible. SHFs analog FIR equalizer module is intended to overcome this commonly encountered measurement problem. True error measurement even of heavily degraded signals is possible as illustrated below.

On the left-hand side, the illustration below shows a 53 GBaud PAM4 signal after transmission. This signal is severely degraded, eye closure in particular, making BER measurements impossible. After equalization, the signal eyes are opened up and freedom from errors (< 10^{-11}) is verified.



Equalizing effect at a 53 GBaud PAM4 signal, BER measurement of that signal

In addition to the factory generated pre-settings of some common universal loss values (typical of coaxial cables), all six equalizer taps are accessible through the complementary software package. Further, a dedicated DSP program “SHF-FIR” can calculate the tap values for optimum equalization. Sophisticated transfer functions can also be compensated; not just simple approximations.

The filter module is available as a stand-alone device rather than built into the error analyzer. This way, it can be used as a remote head placed wherever the equalization has the strongest effect. For example, to generate pre-emphasis at the transmit site, to open small eyes after transmission, close to a DUT in a transmission chain or wherever the need arises.