SHF BERT, DAC & Transmitter for Arbitrary Waveform Generation & Optical Transmission

New:
- Up to 8 channels
- Up to 512 Gbps
All new BPG for SHF’s BERT System

For 20 years now, SHF has been pioneering the market for high speed bit/pulse pattern generators (BPG or PPGs). Now SHF is pushing the limits once more by releasing the all new BPG SHF 12105 A. This BPG is specifically designed to be used not only as a conventional 64 Gbps or 120 Gbps BPG but also as a remote head non-interleaved 60 GBaud Arbitrary Waveform Generator (AWG) when used in conjunction with a high performance SHF DAC.

The well-known key instruments for very high speed BER testing, the SHF 12104 A Bit Pattern Generator (BPG) and the SHF 11104 A Error Analyzer (EA), can be configured in a variety of different channel configurations with a maximum capacity of 264 Gbps per instrument. Now, the SHF 12105 A is raising this limit to 512 Gbps if configured with 8 channels each up to 64 Gbps.

Key Features SHF BPG

- All channels independent (i.e. programmable as it would virtually be a single BPG)
- Synchronized channels for phase and bit alignment (even an inter-channel bit-delay or skew can be set)
- Optional internal output amplifier (option HV)
- Dedicated GUI for PAM generation
- Automation with external software possible (e.g. LabView, VEE, C or Python)

**SHF 12105 A**

- 8 Gbit user pattern memory per each channel in addition to the ITU / CCITT PRBS patterns
- Two auxiliary power outputs for easy connection of SHF remote heads (Multiplexer or DAC)
- Two optional clock outputs for easy connection of remote heads (option addClk)

**SHF 12104 A**

- Cost effective configurations for 60 Gbps ‘only’ available
- 1 Gbit user pattern memory per each channel in addition to the ITU / CCITT PRBS patterns
- Jitter tolerance tests via jitter transfer from clock to data

Typical BPG output waveforms

- 700 mV @ 33 Gbps
- 650 mV @ 64 Gbps
- 2 V @ 64 Gbps (Option HV)
Key Features SHF 11104 A EA

▲ Quick and powerful software routines e.g. for auto-search, Q-factor, jitter, eye contour
▲ New and innovative PAM-4 BER measurement up to 32 GBaud

For PAM-4 signals up to 32 GBaud the EA provides an automated routine to determine the optimum sampling points within each of the concurrent eye openings. The user pattern capability enables the EA to measure the individual error rates in each eye opening to calculate the total aggregated BER of the PAM signal.

BER Measurement and Eye Contour Scan of a PAM-4 Signal
Remote Head 120 Gbps Serial Data Generation

By extending the BPG with one or more remote head SHF multiplexers (Mux) the data rate is doubled and physically close to the device under test. The SHF 12105 A BPG with eight channels can be equipped with up to four of these multiplexers.

Typical Performance Remote Head Multiplexer

60 GBaud Arbitrary Waveform Generation

Combining either the SHF 12104 A or the SHF 12105 A with one of SHF’s digital to analog converters (DACs) converts the system into a multi-channel PAM source. With these BPGs one has full control of the patterns into the DAC (due to the huge memory and the channel synchronization). Therefore, our BPG-DAC combination can be seen as a full blown remote head non-interleaved 60 GBaud Arbitrary Waveform Generator (AWG).

As SHF’s new synthesized clock generators SHF 78122 A (bench-top) and SHF 78212 A (plug-in) operate up to 67 GHz, the clock distribution with the SHF 12105 A can be in ‘full-clock’ mode (e.g. 64 GHz clock for 64 Gbps data from the BPG). The clock required for the DAC can be taken from either the BPG’s standard clock output or from one of the additional two optional clock outputs (option addCLK). Thus no additional components like frequency doublers are required. Even the power for the remote heads can be taken from the SHF 12105 A’s auxiliary power outputs.

This active DAC approach is more versatile, robust and supports more levels compared to simple passive combining. Further, it is faster than any other AWG instrument as it samples only one single time per each bit. Thus the baud rate of the resulting PAM signal is as fast as the sample rate of the system. No other AWG can create 60 GBaud PAM signals of equal signal quality.

Key Features Remote Head AWG

- Sample rate = output baud rate
- 8 GSa waveform memory (in case a SHF 12105 A is used); 1 GSa waveform memory (in case a SHF 12104 A is used)
- Remote head to preserve signal integrity close to the DUT
Speed, vertical resolution and output power depending on the used SHF DACs:

<table>
<thead>
<tr>
<th>SHF DAC</th>
<th>Max. Baud Rate</th>
<th>Max. Vertical Resolution</th>
<th>Max output amplitude @ full scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHF 611 D</td>
<td>32 GBaud</td>
<td>3 bit (8 level)</td>
<td>0.8 V (se) 1.6 V (diff.)</td>
</tr>
<tr>
<td>SHF 612 A</td>
<td>32 GBaud</td>
<td>4 bit (16 level)</td>
<td>0.65 V (se) 1.3 V (diff.)</td>
</tr>
<tr>
<td>SHF 613 A</td>
<td>60 GBaud</td>
<td>3 bit (8 level)</td>
<td>0.65 V (se) 1.3 V (diff.)</td>
</tr>
<tr>
<td>SHF 614 B</td>
<td>60 GBaud</td>
<td>6 bit (64 level)</td>
<td>1.4 V (se) 2.8 V (diff.)</td>
</tr>
<tr>
<td>SHF 615 B</td>
<td>60 GBaud</td>
<td>3 bit (8 level)</td>
<td>2.4 V (se) 4.8 V (diff.)</td>
</tr>
</tbody>
</table>

Typical Performance Remote Head AWG (BPG + DAC)

Channel Count

Expanding the BPG’s capabilities with one of the remote heads increases the speed or the number of levels. The resulting maximum channel count from the remote heads are shown below (mixed configurations would also be possible).

<table>
<thead>
<tr>
<th>Remote Head</th>
<th>BPG Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Bit DAC²</td>
<td>Dual 64</td>
</tr>
<tr>
<td>4-Level, i.e. up to 120 Gbps per channel</td>
<td>1</td>
</tr>
<tr>
<td>3- Bit DAC</td>
<td>8-Level, i.e. up to 180 Gbps per channel</td>
</tr>
<tr>
<td>4- Bit DAC²</td>
<td>16-Level, i.e. up to 240 Gbps per channel</td>
</tr>
<tr>
<td>5- Bit DAC²</td>
<td>32-Level, i.e. up to 300 Gbps per channel</td>
</tr>
<tr>
<td>6-Bit DAC</td>
<td>64-Level, i.e. up to 360 Gbps per channel</td>
</tr>
</tbody>
</table>

¹ A ‘dual’ configuration is available only for the SHF 12104 A, while a ‘hex’ or ‘oct’ configuration is only available for a SHF 12105 A.
² SHF offers only 3- and 6-Bit DACs at this speed. For this configuration a DAC with more input channels has to be utilized by leaving input channels unused.

Ideal to generate DP-16QAM by driving an IQ modulator with 4 uncorrelated PAM-4 signals.

Now, as the SHF 12105 A provides 6 or 8 channels, the full resolution of the 6-Bit DAC can be accessed at 60 G.
Software package with AWG features

A SHF BPG and a SHF DAC are not just two discrete modules connected together. The BCC (BERT Control Center) software provides a variety of features which can be used in case a SHF DAC is connected to the SHF BPG.

For example, one can load any numerical data from computing software such as MATLAB. The software only needs to know which BPG output is physically connected to which DAC input. The BCC will calculate the user pattern for each channel in a way that the DAC generates the arbitrary signal.

Another software module helps to create PAM signals with individual amplitude eye openings. This can be very helpful, for example, to match the used EA modulator. For standard (equal amplitude) PAM-4 only two input bits would need to be used. This feature makes use of the additional bits a SHF DAC can provide (the more bits the finer adjustments can be made between the levels).
Optical Transmission

Expanding the BPG with one of SHF’s optical transmitter plug-ins SHF 46213 D or SHF 46215 B enables the customer to easily generate:

- (D)QPSK up to 66 Gbps, DP-(D)QPSK up to 132 Gbps
- 16QAM up to 132 Gbps & DP-16QAM up to 264 Gbps
- All in NRZ, RZ, or CS-RZ formats

As the internal SHF amplifiers offer an outstanding linearity the plug-ins can transmit QPSK signals as well as QAM or OFDM either on one polarization with the SHF 46213 D or on two polarizations by utilizing the SHF 46215 B.

To perform reliable, repeatable long term measurements, all optical transmitters feature an automatic bias control for all built-in optical modulators to track the modulator optimum DC bias. This and the outstanding signal quality render SHF transmitters to be the reference signal source for many research facilities and industry partners.

Application Example: DP- QAM

The setup below shows how easily a DP-16QAM signal with a total capacity of up to 264 Gbps is generated.

The Bit Pattern Generator produces eight perfectly shaped independent but synchronized data streams of up to 33 Gbps.

A SHF digital to analog converter (DAC) can be used to combine two binary signals to one 4-level signal.

Once these four (I & Q for the X & Y polarization) electrical 4-level data streams are generated it is only a few clicks in the intuitive control software and the SHF 46215 B generates a high quality DP-16QAM optical signal.
Compact BERT Series

The compact BPG series is SHF’s approach of delivering a high performance signal generation solution to the cost-sensitive data-com industry. The minimal power consumption and the light weight make it perfectly suited for on-wafer tests.

To date, the SHF 12124 A offered the lowest cost per bit rate of all bit pattern generators. Its successor, the SHF 12124 B, is now even offering pattern-synchronized channels to enable the generation of true PRBS at even higher speeds via a multiplexer or a DAC. Incorporating such a multiplexer or DAC in the BPG instrument results in our all new SHF 12125 B and SHF 12126 A, respectively.

<table>
<thead>
<tr>
<th></th>
<th>SHF 12124 B</th>
<th>SHF 12125 B</th>
<th>SHF 12126 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 Gbps</td>
<td>2 differential</td>
<td>2 single-ended</td>
<td>2 single-ended</td>
</tr>
<tr>
<td>60 Gbps</td>
<td>---</td>
<td>1 differential</td>
<td>---</td>
</tr>
<tr>
<td>30 GBaud</td>
<td>---</td>
<td>---</td>
<td>1 differential</td>
</tr>
</tbody>
</table>

To complement this BERT system, fitting synthesized clock generators, error analyzers and optical transmitters are available.

**SHF 12124 B, 12125 B & 12126 A BPG**

- Gap-free operation from 5 Gbps (GBaud) to the upper data & baud rate limit
- 4-Tap-FIR for pre-emphasis and skew control over two UI for 32 Gbps NRZ outputs
- PRBS $2^7 - 1, 2^{11} - 1, 2^{15} - 1, 2^{23} - 1, 2^{31} - 1$
- Various clock and trigger outputs

**SHF 11125 A Error Analyzer**

- 2 independent differential input channels up to 32 Gbps
- High Sensitivity (typically 30 mV @ 32 Gbps) and a wide input phase delay range (140 ps)
- Individual or common clock input
- Extensive measurement capabilities such as quick auto-search, Q-factor, jitter and eye contour analysis

**SHF 78120 B & 78122 A Clock Generator**

- Frequency range:
  - 0.625 to 38 GHz (SHF 78120 B)
  - 0.625 to 67 GHz (SHF 78122 A)
- External jitter injection of various types
- Optional internal sinusoidal jitter source
- Selectable trigger output (Clk/2 or Clk/4)

**SHF 46120 C & 46121 B Optical Transmitters**

- ASK and PAM-4 E/O converter
- SHF 46120 C
  - Up to 50 Gbps NRZ, 28 GBaud PAM4
  - 1310 & 1550 nm (O- and C- bands)
- SHF 46121 B
  - Up to 60 Gbps NRZ, 32 GBaud PAM4
  - 1550 nm (C-band)