AN13: Generating 40G PRBS patterns

Centellax designs and manufactures a collection of low-cost instruments and test accessories that can be combined to generate a low-featureset, extremely cost-effective modular 22-44Gbps Bit Error Rate (BER) test system.

The Centellax modular 40G BER test system is described in AN12, available from the Centellax website at: http://www.centellax.com/?TG1P4A

Key component used in 40G BER test system

TG1P4A: 40G PRBS Generator, http://www.centellax.com/?TG1P4A

- 21-44Gbps operating rates
- Internal fixed half-rate clock, or external half-rate clock
- Differential outputs; half-rate clock trigger output

Pseudo-Random Pattern Sequence (PRBS) patterns

In high speed analysis of serial links, it is important to use a data pattern that is very random to appropriately simulate the effects of any conceivable input to the system. An optimal pattern would be non-deterministic and never repeat; an analysis would never be able to predict the next bit value.

However, a key requirement for data integrity testing is a bit error rate (BER) test, which compares bit values measured after transmission through the device under test (DUT) to the bit values of the input signal. If the DUT damages very few bits (or none at all), the BER is very low (or zero), and the device can be considered good.

The BER test requirement complicates the data pattern used to stimulate the DUT. Unless the BER tester knows the pattern of input bits, it can not count errors introduced by the DUT. A perfectly-random non-deterministic pattern can not be used; the solution is a PRBS pattern.

A PRBS pattern is an encoded ‘optimally’ random NRZ sequence of bits generated by a complex polynomial equation. The PRBS pattern has a seed, is deterministic, and is not a truly random pattern (thus the name pseudo-random), but a PRBS pattern is the best input signal for testing your device performance.

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PRBS pattern definitions

PRBS patterns are typically described by the shorthand notation "2^X-1". The power, X, indicates the length of the shift registers used to create the pattern, and every possible combination of the X number of bits (minus one). The X value also indicates the longest series of 0's and 1's present in one pattern.

A 2^{31}-1 PRBS generates a pattern greater than 2.1Gb long and provides the low frequency content that is appropriate for SONET and SDH telecommunications system tests. Other shorter patterns are good for testing Ethernet, Fiber Channel, or high speed video applications.

The Centellax TG1P4A generates the following PRBS patterns at any rate from 21-44Gbps:

PRBS pattern	Polynomial	Standard	Number bits	Patterns / second at 10Gbps
2^7-1	$1+X^4+X^7$		127	78,740,157
2^{15}-1	$1+X^{14}+X^{15}$	ITU-T O.150	32,767	305,185
2^{31}-1	$1+X^{28}+X^{31}$	ITU-T O.150	2,147,483,647	4.65

PRBS patterns have the following distinctive characteristics:

- PRBS patterns have a sync-function spectral density
  - This is carefully aligned with communication standards, such that a 9.95328Gbps PRBS bitstream required for SONET testing will have a sync pattern spectral density with nulls at 9.95328GHz and 19.90656GHz
- PRBS patterns can be de-multiplexed into lower-rate PRBS patterns
  - Eg: 40G PRBS 2^^{31}-1 pattern can be demux'd into four 10G PRBS 2^^{31}-1 patterns
- PRBS patterns can be generated by multiplexing lower-rate PRBS patterns
  - Eg: 40G PRBS 2^^{31}-1 pattern can be generated by multiplexing four 10G PRBS 2^^{31}-1 patterns together

The multiplexing and de-multiplexing aspects of PRBS bitstreams are important!

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De-multiplexing PRBS bitstreams into lower-rate PRBS bitstreams

The ability to de-multiplex (demux) a PRBS bitstream into lower-rate PRBS bitstreams of the same PRBS pattern makes testing high-bitrate systems easier and less expensive.

For example, a 40Gbps BER test system can be comprised of a 40G PRBS generator, a 40G demux, and one or more 10G BER testers. By testing each of the four channels from the demux sequentially, only one 10G BERT is required and the cost of test is reduced. This application is described in AN12, available online from: http://www.centellax.com/?TG1P4A

Multiplexing lower-rate PRBS bitstreams into higher-rate PRBS bitstreams

Multiplexing four PRBS bitstreams into a higher-rate PRBS bitstream is very challenging – it requires offsetting the input patterns by exactly pattern_length/4.

Offsetting four PRBS bitstreams requires:

- Four PRBS generators driven with a synchronous clock (phase-matched cables and phase-matched splitters required)
- Simultaneous PRBS generator reset capability with 0-bit accuracy
- Phase-matched cables from PRBS generators to phase shifters, and from phase shifters to MUX input (matched with another single cable for the un-skewed channel)
- Adjustable bit-accurate phase shifters with huge dynamic range (32 bits for PRBS7, 536,870,912 bits for PRBS31) on three of four inputs to MUX

If the four inputs to the MUX are not correctly offset, the 40G bitstream generated will NOT be a PRBS pattern.

A 40G bitstream that is not a PRBS pattern will:

- NOT have the sync function spectral density
- NOT have the 31 1's and 31 0's associated with a PRBS31 pattern
- NOT have the very low-frequency content a PRBS pattern has
- NOT provide the 'most random' collection of bits possible
- NOT test the DUT in a similar manner to a true PRBS pattern

Given the difficulty associated with offsetting input bitstreams, Centellax recommends a true 40G PRBS generator for 40G test systems. The TR1P4A is a true 40G PRBS generator. Details online: http://www.centellax.com/?TR1P4A.