Keysight Technologies
N4917B Optical Receiver Stress Test Solution

100GBASE-LR4/ER4/SR4

Solution Brochure

KEYSIGHT
TECHNOLOGIES
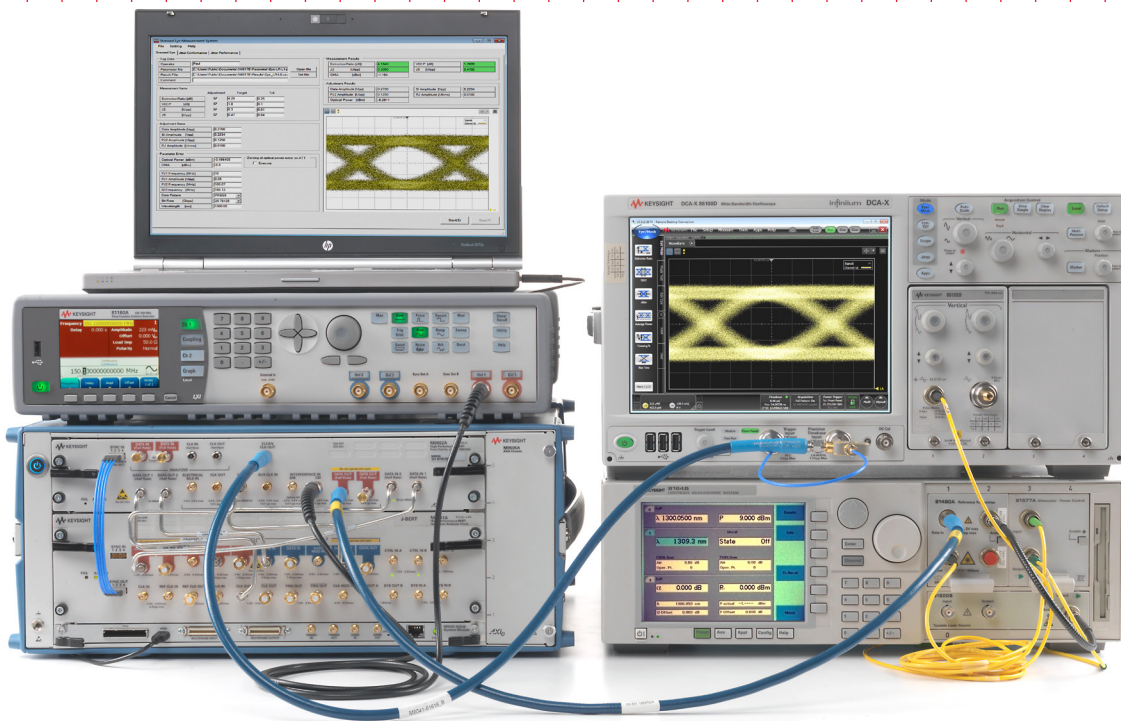
Unlocking Measurement Insights

Repeatable Optical Receiver Stress Test for 100GBASE-LR4/ER4/SR4

In recent years, transmission speeds in gigabit ethernet have continously increased from 10 Gb/s to 40 Gb/s and are now approaching the 100 Gb/s speed class. 10 Gb/s Ethernet was designed based on a 10.3125 Gb/s line rate on one single-mode fiber per direction. The 40 Gb/s Ethernet speed class changed this to an architecture using the same 10.3125 Gb/s line rate but using four optical wavelengths in the O-Band on one single-mode fiber per direction. This increased the transmission capacity by a factor of four, without a need to make changes to the speed of the electrical components. In the last few years the 100 Gb/s speed class has been established, increasing the electrical line rate from 10.3125 Gb/s to 25.78125 Gb/s. It also uses both four optical wavelengths on one fiber as well as multiple fibers with one optical wavelength per fiber.

The conformance test specification for 100 Gb/s transmission speed class is defined in the IEEE 802.3 standard, clause 88 for 100 Gb/s Ethernet long reach (LR4) and extended reach (ER4) and clause 95 for 100 Gb/s Ethernet short reach (SR4).

The N4917B optical receiver stress test solution provides an automated stressed receiver sensitivity test in accordance with the 100GBASE-LR4, ER4 and SR4 test specifications. In order to do this kind of test, several test instruments such as a bit error ratio tester, digital sampling oscilloscope, optical reference transmitter and tunable laser source are required to operate together to achieve a compliant, repeatable optical stressed eye. This stressed eye is then fed to the receiver under test, where bit error ratio is measured under the stress conditions as defined in the standard.

The N4917B solution provides:
– Automated calibration of the optical stressed eye according to IEEE 802.3 clause 88 and 95.
– Calibration of ER, VECP/SEC, J2, J4, J9, OMA parameters
– Repeatable results
– Adjustable target values for ER, VECP/SEC, J2, J4, J9, OMA
– Jitter tolerance compliance and margin test
– Electrical loop back or optional DUT control interface for full automated JTOL test
– Remote control of all the test instrumentation
– For this, the N4917B includes the following key equipment:
  – a high performance bit-error-rate tester
  – an optical reference transmitter for 25.78125 Gb/s
  – a tunable laser covering the O-band for LR4/ER4 or a 850nm laser for SR4

Optical Stress Test Typical Setup For 100GBASE-LR4/ER4 and SR4

The N4917B optical receiver stress test solution consists of a BERT plus a sinewave generator for electrical signal and stress generation; an electro-optical converter that modulates the optical signal and a digital sampling oscilloscope/CDR which is required for calibration of the stressed eye. Example setups for LR4/ER4 and SR4 are shown in the figures below. See the configuration guide for a full list of supported instruments.
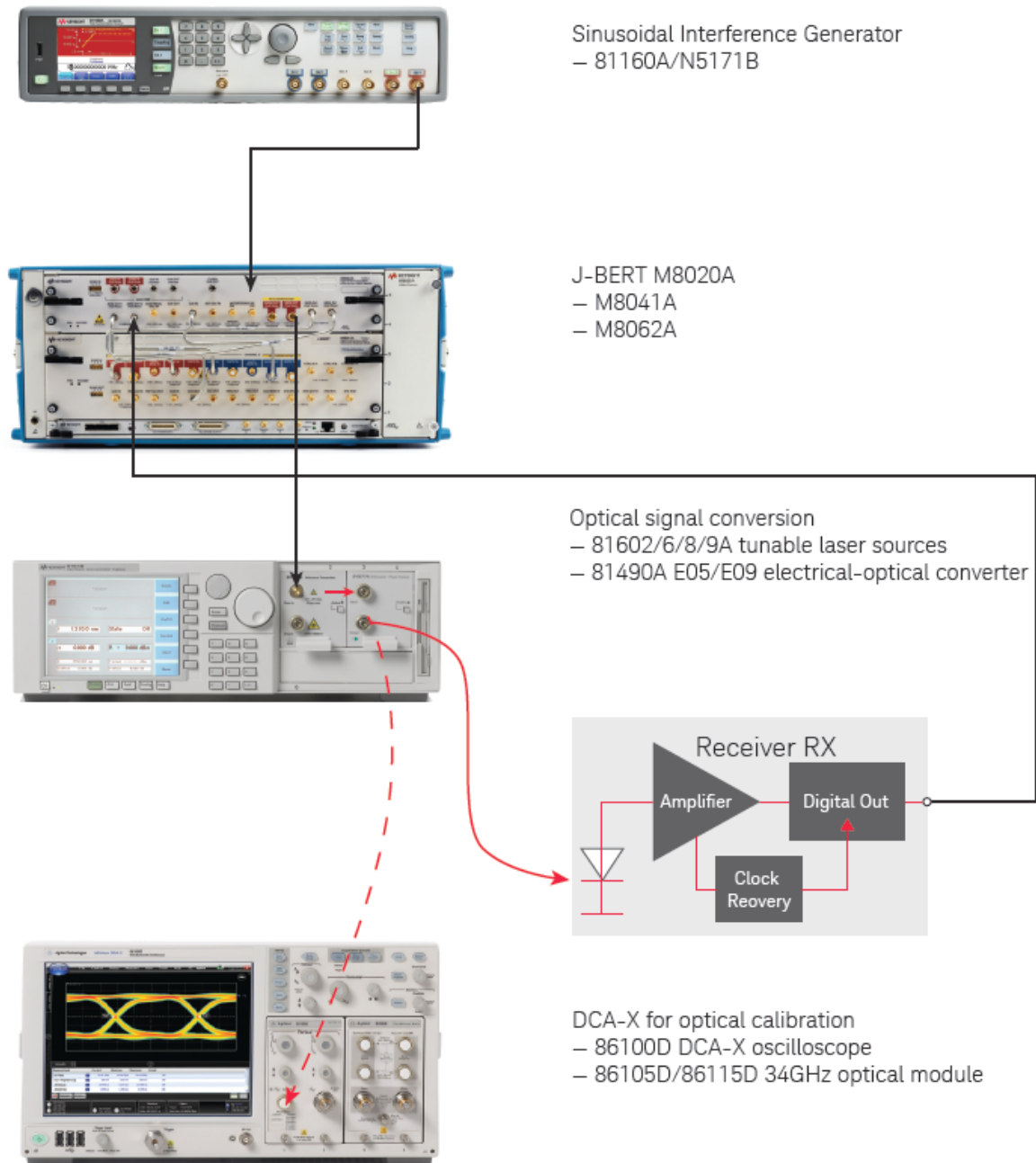
Sinusoidal Interference Generator
— 81160A/N5171B

J-BERT M8020A
— M8041A
— M8062A

Optical signal conversion
— 81602/6/8/9A tunable laser sources
— 81490A E05/E09 electrical-optical converter

Receiver RX

Amplifier

Digital Out

Clock Reovery

DCA-X for optical calibration
— 86100D DCA-X oscilloscope
— 86105D/86115D 34GHz optical module

Figure 1. Example setup for 100GBASE-LR4/ER4.

Sinusoidal Interference Generator
- 81160A/N5171B

J-BERT M8020A
- M8041A
- M8062A

Optical signal conversion
- 81490A E10 electrical-optical converter

Clock recovery
- N1077A optical/electrical clock recovery

Receiver RX

Amplifier

Digital Out

Clock Reovery

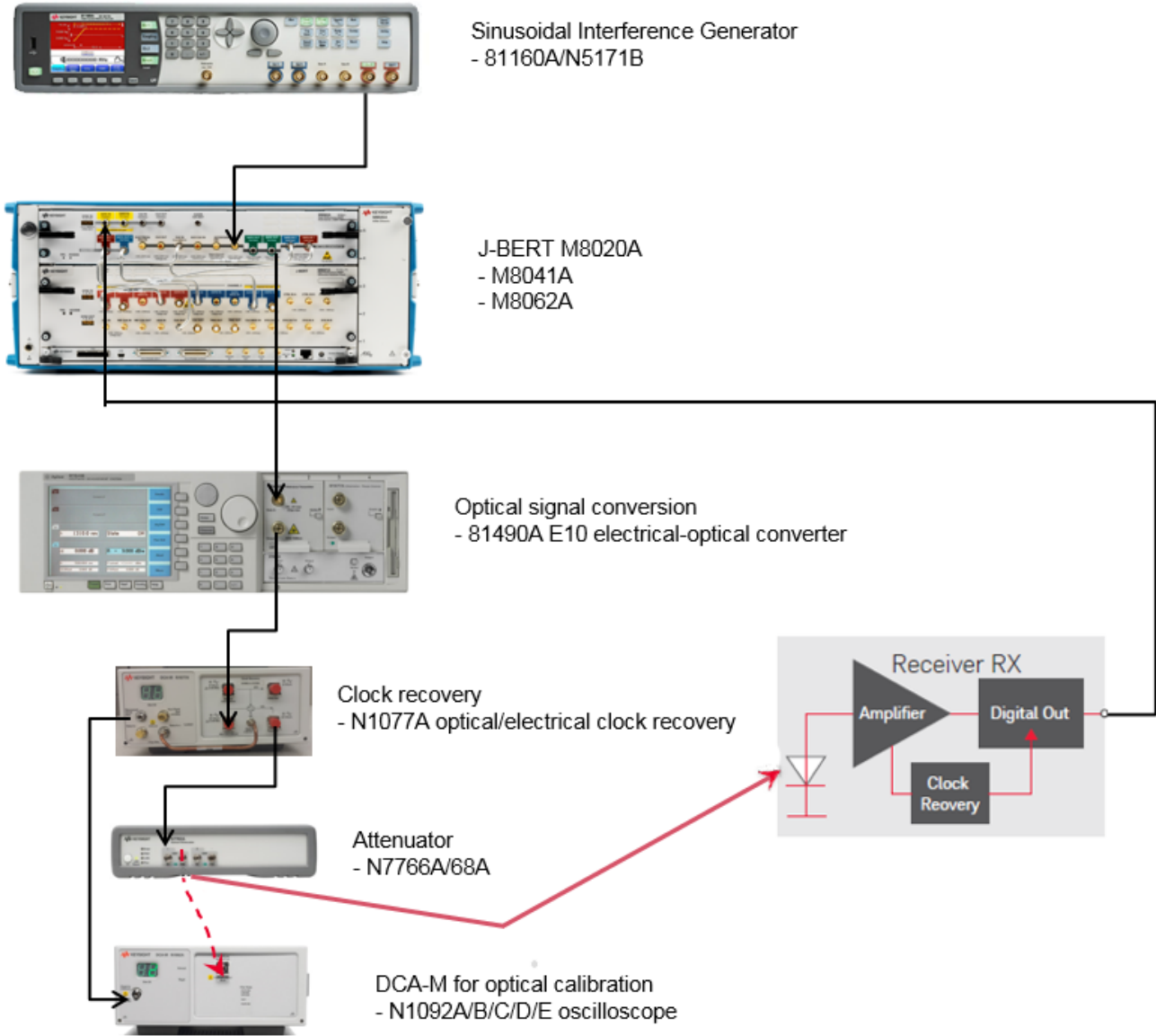Attenuator
- N7766A/68A

DCA-M for optical calibration
- N1092A/B/C/D/E oscilloscope

Figure 2. Example setup for 100GBASE-SR4.

100GBASE-LR4/ER4/SR4 Optical Stressed Eye Test Challenges

The IEEE 802.3 standard, clauses 88.7, 95.7 describe the optical specifications for 100GBASE-LR4, -ER4 and -SR4 optical receivers. The following table contains the salient conditions required for stressed receiver sensitivity test.

Parameter description	100GBASE-LR4	100GBASE-ER4	100GBASE-SR4
Stressed receiver sensitivity (OMA), lane under test (max)	−6.8 dBm	−17.9 dBm	−5.2 dBm
Extinction ratio (with jitter and interferers off)	4 dB	8 dB	2 dB
Conditions of stressed receiver sensitivity test			
Vertical eye closure penalty (VECP), lane under test	1.8 dB	3.5 dB	-
Stressed eye closure (SEC), lane under test	-	-	4.3 dB
Stressed eye J2 jitter, lane under test	0.3 UI	0.3 UI	0.39 UI
Stressed eye J4 jitter, lane under test	-	-	0.53 UI
Stressed eye J9 jitter, lane under test	0.47 UI	0.47 UI	-
Stressed receiver eye mask definition {X1,X2,X3,Y1,Y2,Y3} Hit ratio 5E-5 hits per sample	-	-	{0.28,0.5,0.5,0.33,0.33,0.4}

Setting up a stressed eye according to the standard can be a very time consuming task, even for experienced users it can take a half day. The reason is that the stressed eye parameters are interdependent and therefore several iterations of the optimization cycle are required to converge on the solution. In addition, it is important that the setup is repeatable and remains stable from the time of the stressed eye calibration through to the end of the DUT measurement. Otherwise a drift in the test setup, especially in the electro-optical converter will impair the test results.

The N4917B optical receiver stress test solution provides a repeatable and stable measurement in a fraction of time compared to manual setup of the stressed eye. This offers major time saving during daily measurements and speeds up developing a standard compliant test solution when compared to a self made solution.
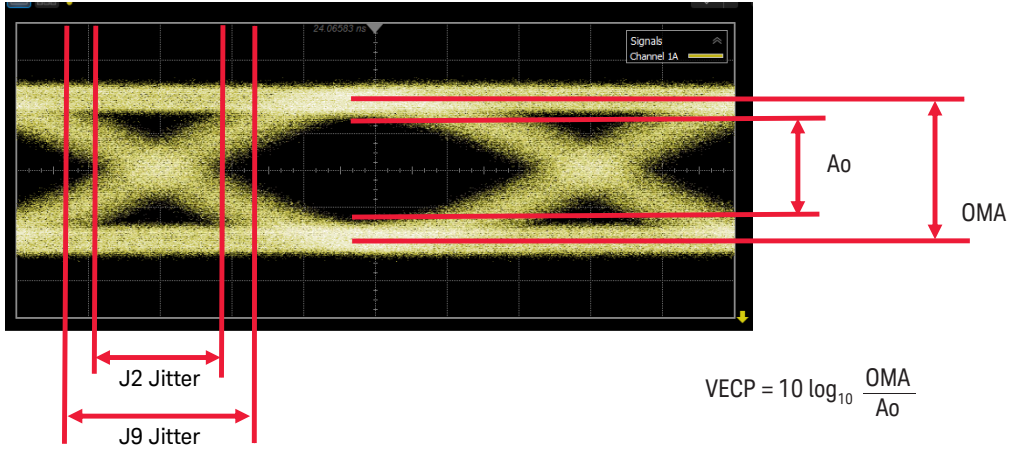
$$VECP = 10 \log_{10} \frac{OMA}{Ao}$$

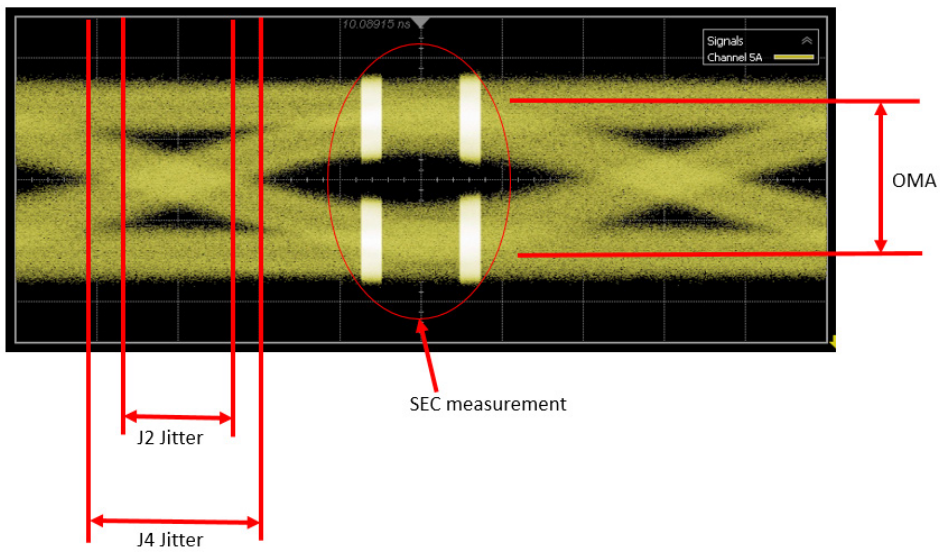Figure 3. Definition of 100GBASE-LR4/ER4 optical stress parameters.

Figure 4. Definition of 100GBASE-SR4 optical stress parameters.

N4917B Detailed Test Setup

The core instrument of the optical stressed eye test setup is the J-BERT M8020A High-Performance BERT system that provides an electrical signal with all the required impairments (random and sinusoidal timing jitter, ISI and sinusoidal amplitude interference) at the data signal output, using a combination of its built-in stress sources plus an external generator. This electrical signal is fed into the 81490A electrical-optical converter to modulate the laser and create the stressed optical signal. For LR4/ER4, an 8160xA tunable laser is used to set the wavelength for each of the four lanes in turn. For SR4, all lanes operate at a fixed wavelength, using the 81490A internal laser source. The optical output of the 81490A is then attenuated to get to the required optical power level at the input of the receiver under test.

Prior to testing the receiver, the optical signal for each wavelength is calibrated using the 86100D Infiniium DCA-X Wide-Bandwidth Oscilloscope with 86105D optical module or using the N1092x DCA-M. All of the equipment is under control of the N4917B software, which takes care of the various equipment settings and performs an iterative adjustment of the BERT stressess until the optical signal measured on the DCA meets the required stressed eye parameters (ER, VECP/SEC, J2, J4/J9, Eye Mask).
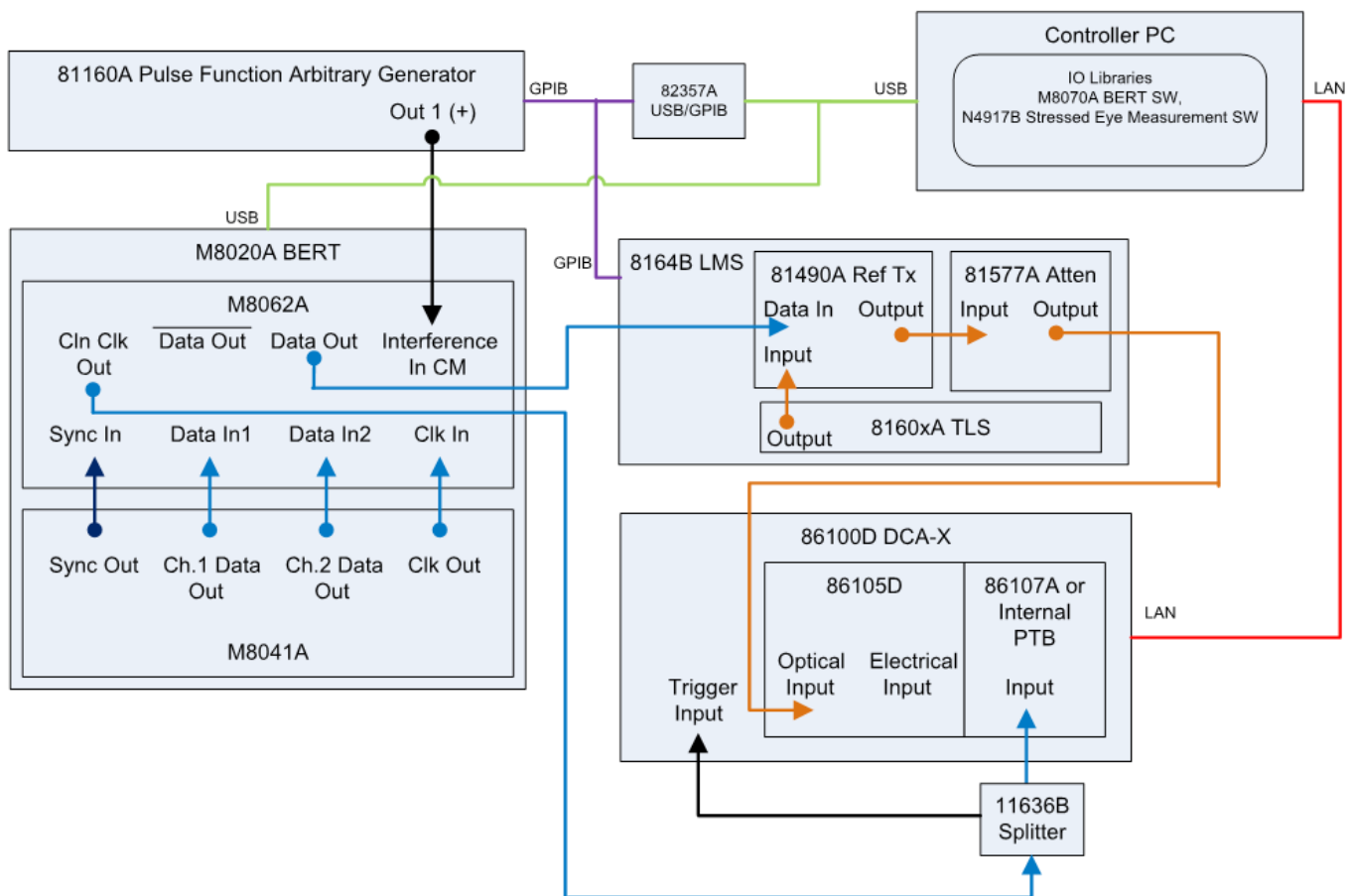

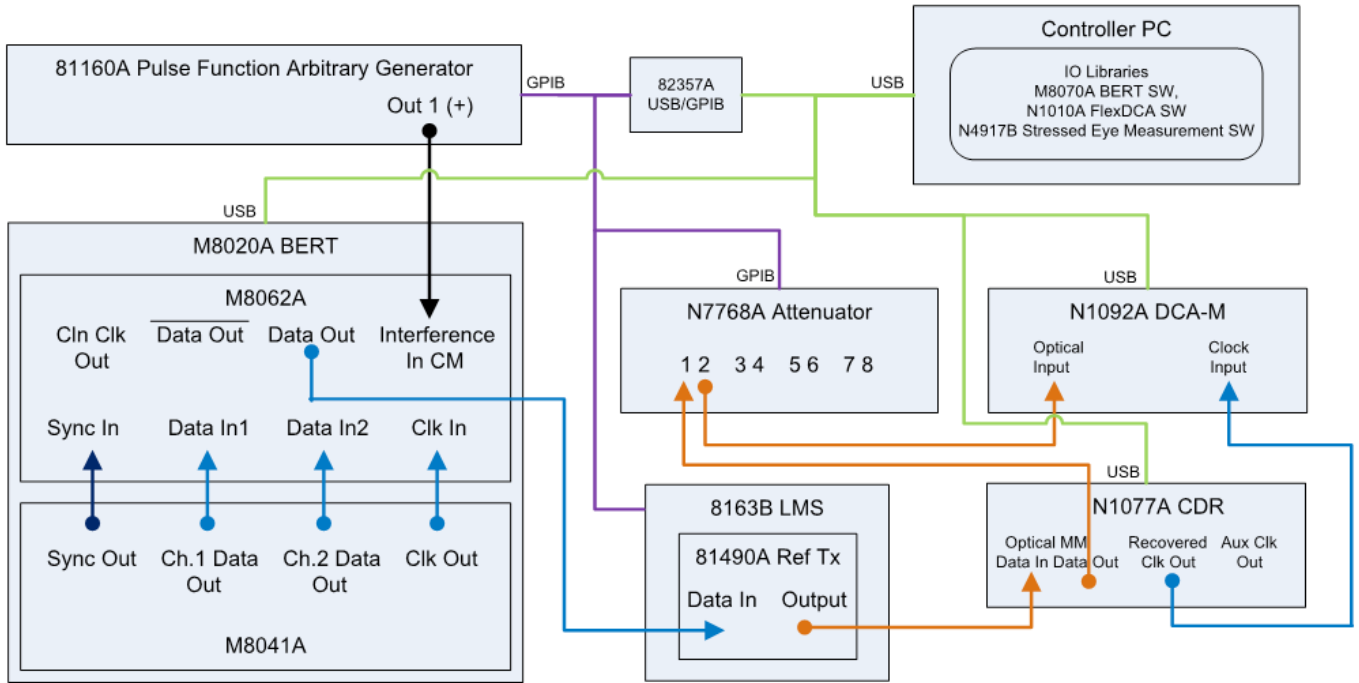Figure 5. Example connection diagram for 100GBASE-LR4/ER4 single-mode optical receiver stress test solution.

Figure 6. 100GBASE-SR4 multimode optical receiver stress test solution.

N4917B Detailed Test Setup

After the calibration step, each lane of the DUT should be tested in turn, with valid signals present on the other lanes. Exact connection details and setup depend on the type of device being tested. A couple of examples are shown below.

LR4 Transceiver Test

In this example an optical de-multiplexer is used to bring out the four lanes on four individual fibers. Attenuators in each lane are used to set the relative optical modulation amplitude (OMA) with respect to the lane under test. The calibrated stressed eye signal is connected to the lane under test at the optical mulitplexer which combines all four lanes onto one fiber.

BER measurement during the Jitter Tolereance test sweep can either be read from the device under test or optionally looped back to the BERT for fully automated JTOL testing.

Figure 7. Example 100GBASE-LR4 setup for running a stressed receiver sensitivity test on a device.

SR4 Transceiver Test

In this example, there are four separate fibers, carrying one signal per fiber. Attenuators in each fiber are used to set the relative optical modulation amplitude with respect to the lane under test. The calibrated stressed eye signal is connected to the lane under test.

BER measurement during the Jitter Tolereance test sweep can either be read from the device under test or optionally looped back to the BERT for fully automated JTOL testing.
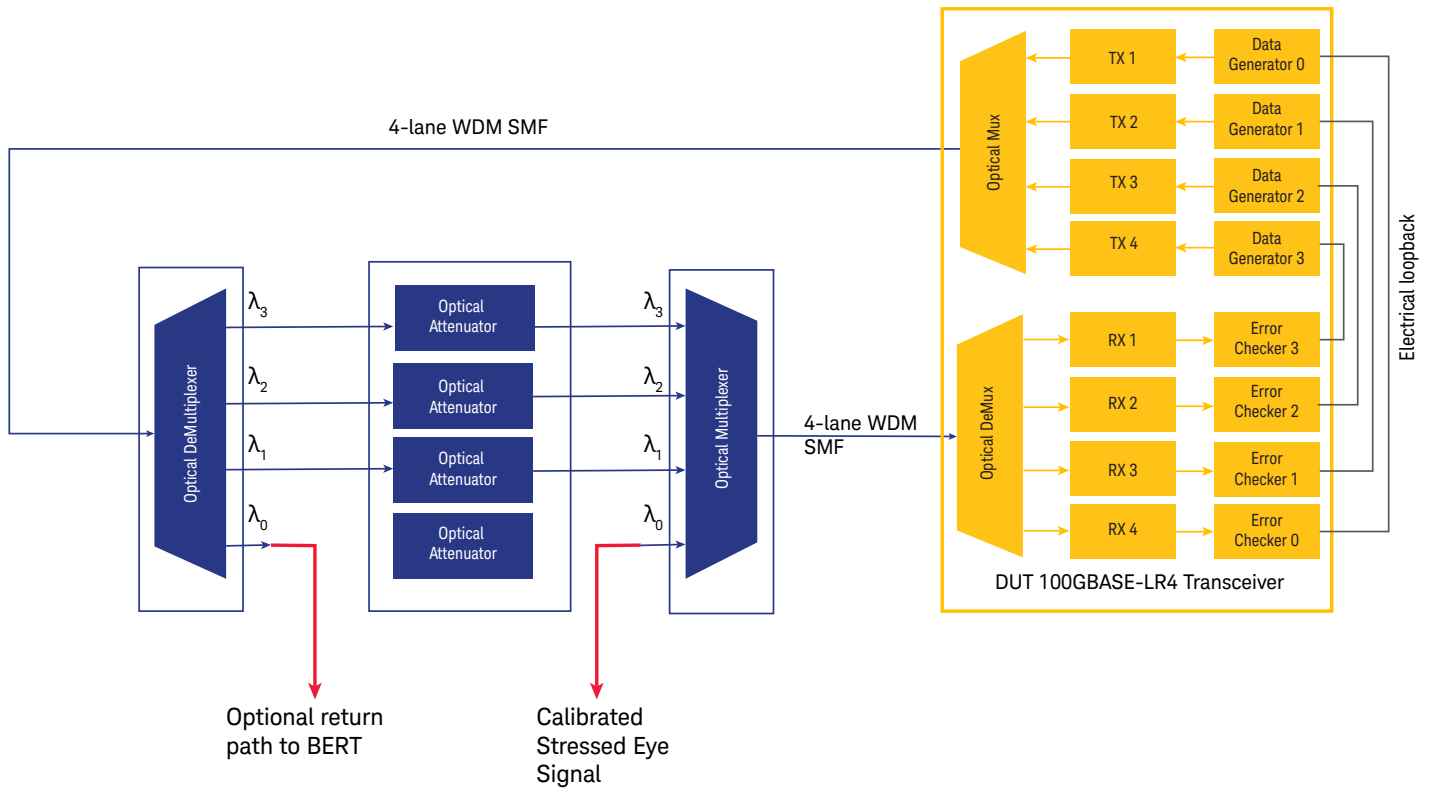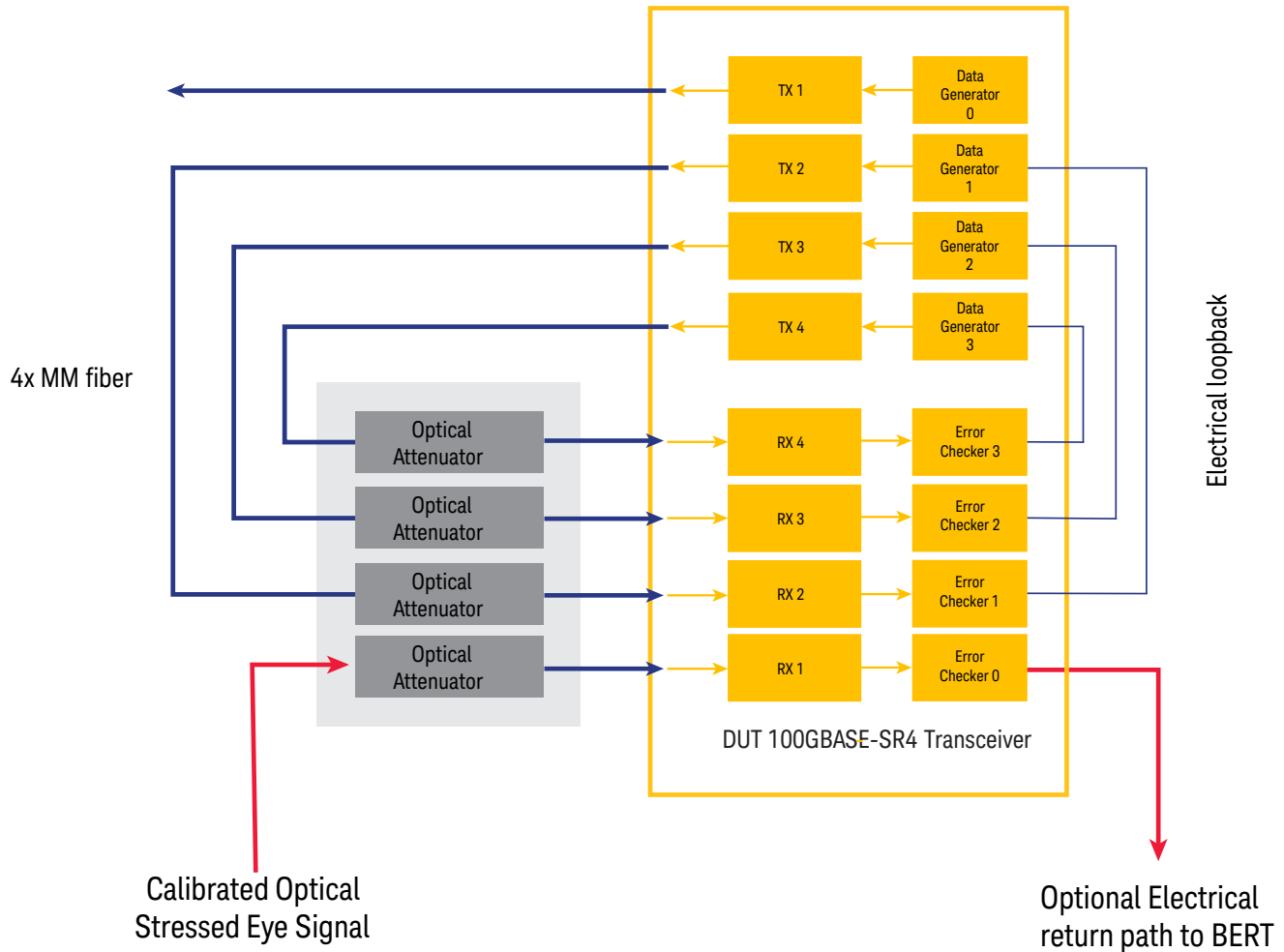
Example 100GBASE-SR4 setup for running a stressed receiver sensitivity test on a device

Figure 8. Example 100GBASE-SR4 setup for running a stressed receiver sensitivity test on a device

N4917B User Interface

The N4917B optical receiver stress test solution controls all of the instruments via USB, LAN or GPIB connections.

The main screen of the N4917B software, the Stressed Eye tab, provides setting of the paramaters required for the calibration of the stressed eye, runs the stressed eye calibration and displays the results for the calibrated stressed eye components.

The two remaining tabs — Jitter Conformance and Jitter Performance are used when testing the device for compliance or margin testing.
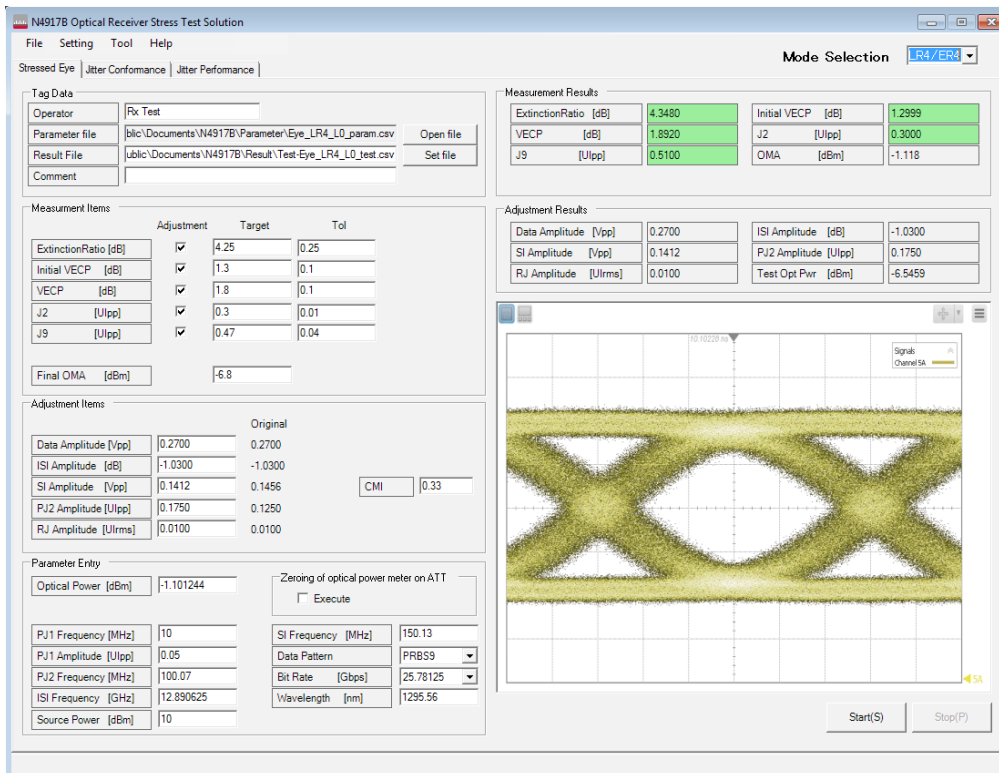

Figure 9. shows the stressed eye screen for 100GBASE-LR4 to setup the desired calibration parameters: extintion ratio, vertical eye closure penalty, J2 and J9 jitter. In addition, various other parameters can be modified for individual setups.

N4917B Jitter Conformance And Performance Tests

The stressed receiver sensitivity test explained in the IEEE 802.3 standard requires a sweep of sinusoidal jitter on top of the previously calibrated jitter and the interference stress and at a specific OMA level. The DUT must meet or exceed the target Bit Error Ratio under these conditions (1E-12 for LR4/ER4 and 5E-5 for SR4).

The N4917B software provides two jitter measurements. The Jitter conformance tests per the compliance level in the standard and the optional user selectable margin can be applied to test at a slightly higher level than the standard requires. The Jitter Performance test allows the user to find the limits of the jitter tolerance test for more detailed margin testing.

Results of the jitter measurements are shown numerically and graphically. In example below, the blue line on the plot is the jitter tolerance compliance limit from the IEEE 802.3 standard. The green dots represent actual test data, at the user selectable margin. The yellow line indicates the maximum margin limits of the jitter tolerance test.

In these tests the stress level is automatically setup by the N4917B software, using a previously run calibration and the user enters the BER results manually. This test is most approriate when the BER can be visually read from the DUT user interface.
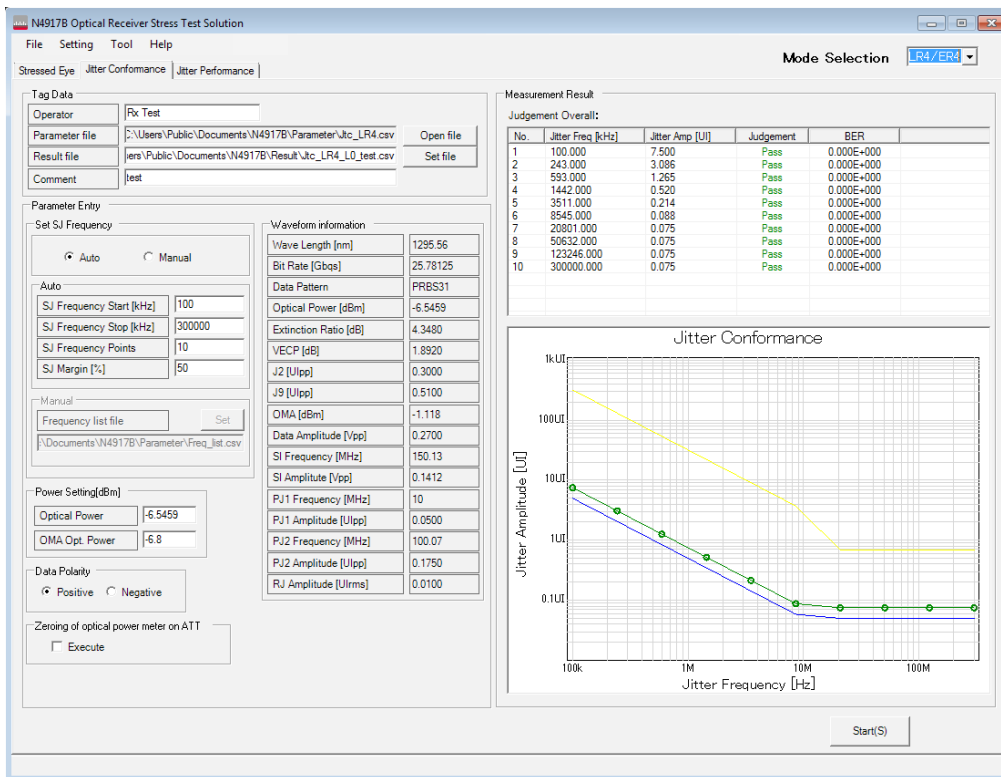

Figure 10. Screenshot jitter conformance result

N4917B Jitter Conformance And Performance Tests

Depending on the test setup and DUT capabilities, it is also possible to run fully automated jitter tolerance measurements using built-in JTOL measurement within the M8070A System Software.

This test is used when either:
a. the DUT can be put into loopback mode and a signal from the lane under test is fed back to the BERT, or
b. the DUT can be controlled directly from the M8070A software using the DUT Contol Interface (license required) to read the BER directly from the DUT internal error checker counters.

The M8070A JTOL measurement can also be run as a compliance test with/without margin or a tolerance test to find the limits of the DUT. It has several additional features such as a choice of search algorithm, user definable BER depth, etc.
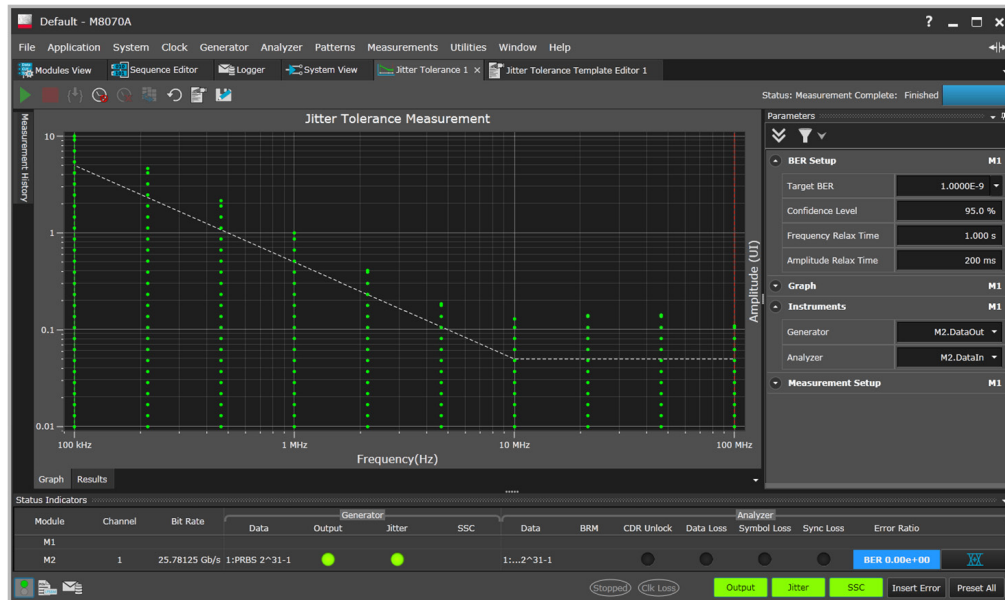

Figure 11. Jitter tolerance measurement result screen within M8070A system software.

N4917B Features

The N4917B software creates a stressed eye optical waveform from the following setting parameters. Setup files contain recommended values for each lane of LR4, ER4 and SR4. Additionally the user can adjust the parameter values if required prior to a calibration.

Settable parameters

– Data Amplitude (mV pp) *
– Sinusoidal Interferer Amplitude (mV pp) *
– Sinusoidal Interferer Frequency (MHz)
– Periodic Jitter 1 Amplitude (UI)
– Periodic Jitter 1 Frequency (MHz)
– Periodic Jitter 2 Amplitude (UI) *
– Periodic Jitter 2 Frequency (MHz)
– Random Jitter Amplitude (mUI) *
– Bit Rate (Gb/s)
– Optical Power for calibration (dBm)
– OMA for DUT test (dBm)
– Optical Wavelength (nm) (LR4/SR4 only)
– De-emphasis cursors (dB)
– ISI (dB/GHz) *

* These values will be adjusted by the software during the calibration process to meet the calibration parameter targets

Calibration & measurement parameters

– Extinction Ratio (dB)
– VECP (dB) or SEC (dB)
– J2 Jitter (UI)
– J9 Jitter (UI) or J4 Jitter (UI)
– OMA for DUT test (dBm)
– Jitter Conformance pass/fail (UI)
– Jitter Performance margin (UI)

N4917B Requirements

N4917B software runs on an external PC

PC HW Requirements

Operating System: Microsoft Windows 7 (64 bit)
Memory: 8 GB RAM minimum
Monitor Resolution: WXGA+ (1440 x 900) minimum

PC Installed SW Requirements

Keysight IO Libraries Suite rev. 17.2.x or later
M8070A System Software for M8000 Series version 3.5.100.2 or later
N1010A FlexDCA Remote Access System A.05.51 or later (if using DCA-M)

PC Interfaces

USB, LAN

Instrument Firmware Requirements

M8020A J-BERT : M8070A System Software as above
81600D DCA-X: FlexDCA version A.05.51 or later
8164B LMS: version V5.25 or later
81490A Ref Tx: version V5.01 or later

Configuration Guide

The N4917B optical stress test solution is built up from a variety of instruments. For some of the instruments, alternative selections are supported by the N4917B software. Each instrument is an individual order and not part of a bundle. This configuration guide is designed to help you determine which instruments you may already have, and which instruments will need to be ordered to make up a complete optical stressed eye test solution.

1) Select the configuration for the J-BERT M8020A and sinusoidal interference generator

Step 1. BERT chassis configuration	
M8020A	**J-BERT High-performance BERT**
M8020A-BU2	M9505A 5 Slot AXIe chassis with USB option (requires external PC with USB connection)
Step 2. 1st BERT module minimum required configuration	
M8041A	**J-BERT High Performance BERT Module**
M8041A-C16	BERT one channel, 16 Gb/s
M8041A-0G2	Second channel for pattern generator
M8041A-0A2	Second channel for analyzer
M8041A-0G3	Advanced jitter sources
Step 3. 2nd BERT module minimum required configuration	
M8062A	**High Performance BERT module, 32 Gb/s front end**
M8062A-C32	32 Gb/s BERT front end
M8062A-0G4	Multi-tap de-emphasis
M8062A-0G5	Adjustable Intersymbol Interference
M8062A-0A4	Clock Recovery (optional). Needed if looping back DUT to BERT for BER measurement
Step 4. M8000 System Software configuration	
M8070A	**System Software for M8000 Series of BER Test Solutions** Select one of the M8000 System Software licence options
M8070A-0TP	System Software for M8000 Series of BER Test Solutions, Transportable, Perpetual License
M8070A-0NP	System Software for M8000 Series of BER Test Solutions, Network/Floating, Perpetual License
	Select one of the M8000 DUT Control Interface licence options (if reading BER from DUT)
M8070A-1TP	DUT Control Interface, Transportable, Perpetual License (optional)
M8070A-1NP	DUT Control Interface, Network/Floating, Perpetual License (optional)
Step 5. Sinusoidal Interference Source minimum required configuration (select one of the listed signal generators for sinusoidal interference)	
81160A	**1 or 2 Channel Pulse Function Arbitrary Generator**
81160A-001	1 Channel 330 MHz Pulse Function Arbitrary Generator
N5171B	**EXG X-Series RF Analog Signal Generator**
N5171B-503	Frequency Range, 9 kHz to 3 GHz (Note: can be any other generator from the EXG/MXG/PSG family)

Configuration Guide (continued)

2) Select the configuration for the optical components of the solution

Step 6. Lightwave Measurement System mainframe (select on of the Lightwave Measurement System mainframes)	
8163B	**2-slot Lightwave Measurement System mainframe (recommended for SR4)**
8164B	**5-slot Lightwave Measurement System mainframe (recommended for LR4/ER4)**
Step 7. Tunable Laser Source configuration - required for LR4/ER4 only (select one of the tunable lasers)	
81602A	**Extra High Power Tunable Laser**
81602A-013	1250 nm to 1370 nm wavelength range, +17 dBm peak
81606A	**Tunable Laser Family, high Power with low SSE**
81606A-113	Tunable laser source 1240 nm to 1380 nm, +13 dBm peak
81608A	**Tunable Laser Family, Value line, High Power low SSE**
81608A-113	Tunable laser source 1240 nm to 1380 nm, +13 dBm peak
81609A	**Tunable Laser Family, Basic line, High Power low SSE**
81609A-113	Tunable laser source 1240 nm to 1380 nm, +13 dBm peak
	Optical connector interface
81000NI	Connector interface, FC - narrow key way (1 required)
Step 8. Electrical–Optical Converter configuration	
81490A	**Reference Transmitter**
	Select one of the Single-Mode Fiber Reference Transmitters for LR4/ER4 only
81490A-E09	Ref Tx special with external laser input and internal 1310/1550 nm laser
81490A-E05	Ref Tx special with external laser input and without internal laser
	Multi-Mode Fiber Reference Transmitter for SR4 only
81490A-E10	Ref Tx special with 850 nm laser and up to 26 GHz electrical bandwidth
	Optical connector interface
81000FI	FC/PC Interface (1 required for -E05, -E09)
81000NI	Connector interface, FC - narrow key way (1 required for -E05, -E10, 2 required for -E09)
Step 9. Optical Attenuator configuration (select one of the Single-Mode Fiber Attenuators for LR4/ER4 only)	
81576A	**Optical Attenuator high power, power control, straight SMF**
81000FI	FC/PC Interface
81577A	**Optical Attenuator high power, power control, angled SMF**
81000NI	Connector interface, FC - narrow key way
N7761A	Optical Attenuator (1 channel), SMF
N7761A-022	Angled Connectors
N7762A	**Optical Attenuator (2 channels), SMF**
N7762A-022	Angled Connectors
N7764A	**Optical Attenuator (4 channels), SMF**
N7764A-022	Angled Connectors
	Select one of the Multi-Mode Fiber Attenuators for SR4 only
N7766A	**Optical Attenuator (2 channels), MMF**
N7766A-050	50/125 um multimode fiber interface
N77684A	**Optical Attenuator (4 channels), MMF**
N7768A-022	50/125 um multimode fiber interface

Configuration Guide (continued)

3) Select the configuration for the DCA and N4917B software components of the solution

Step 10. Optical/Electrical Clock Recovery for SR4 only	
N1077A	**Optical/Electrical Clock Recovery**
N1077A-232	Supported input rates: 50 MBd to 32 GBd
N1077A-SMS	Internal single-mode (9/125 um) and multimode (50/125 um) splitter
Step 11. DCA minimum required configuration (select either a DCA-X mainframe/plugin/timebase or a DCA-M model/FlexDCA SW configuration) **DCA-X mainframe minimum required configuration**	
86100D	**Infiniium DCA-X Oscilloscope mainframe**
86100D-ETR	Enhanced Trigger, 13 GHz BW, pattern and module trigger
86100D-PTB	Internal Precision Timebase
86100D-200	Enhanced Jitter Analysis SW
86100D-300	Advanced Amplitude Analysis/Rin/Q-Factor
	DCA-X Module. Select one of the DCA-X- Modules, minimum required configuration
86105D	**Module, 34 GHz optical/50 GHz electrical, 750-1650 nm SMF/MMF**
86105D-281	34 GHz optical/50 GHz electrical hardware
86105D-IRC	Optical channel impulse response measurement/data
86115D	**Module, 20/34 GHz optical, 750-1650 nm SMF/MMF**
86115D-282	Dual input 28GHz optical sampling module 750-1650nm for SM and MM fiber
86115D-IRC	Optical channel impulse response measurement/data
	DCA-M minimum required configuration (select one DCA-M model)
N1092A	**One optical channel**
N1092B	**Two optical channels**
N1092C	**One optical, two electrical channels**
N1092D	**Four optical channels**
N1092E	**Two optical, two electrical channels**
	DCA-M minimum required option configuration
Option LOJ	Reduce residual jitter from 400 fs to < 200 fs
Option PLK	Pattern Lock capability
Option IRC	Extend optical channel bandwidth to 45 GHz and allow creation of reference receiver filters at any data rate from 8 to 42 Gb/s
Option 200	Enhanced Jitter Analysis, transportable license (can also be ordered as N1010A-200 FlexDCA license)
Option 300	Advanced Amplitude Analysis/Rin/Q-Factor, transportable license (can also be ordered as N1010A-200 FlexDCA license)
Option 500	Productivity Package, transportable license (Rapid Eye, TDEC) (can also be ordered as N1010A-200 FlexDCA license)
N1010A	**FlexDCA Remote Access Software**
Step 12. N4917B Optical Receiver Stress Test Software configuration	
N4917B	**Optical Receiver Stress Test Solution Software**
	Select one of the N4917B Single-Mode Fiber licence options for LR4/ER4 only
N4917B-0TP	Optical Receiver Stress Test Solution for 100GBASE-LR4/ER4, transportable, perpetual License
N4917B-0NP	Optical Receiver Stress Test Solution for 100GBASE-LR4/ER4, network/floating License
	Select one of the N4917B Multi-Mode Fiber licence options for SR4 only
N4917B-1TP	Optical Receiver Stress Test Solution for 100GBASE-SR4, transportable, perpetual License
N4917B-1NP	Optical Receiver Stress Test Solution for 100GBASE-SR4, network/floating License

Configuration Guide (continued)

4) Select the accessory components of the solution

Step 12. Select accessoires as needed	
N4917B-800	Fiber Optic cable, PMF, protected 37 cm narrow key FC/APC (only required for 81490A-E05)
N4917B-801	Cable assembly coaxial Rg/223 50 Ω BNC (male) to BNC (male)
N4917B-802	Adapter-coaxial straight (female) BNC (male) SMA
N4917B-803	Patchcord FC/PC-FC/PC connector SM fiber 2 m
N4917B-804	Patchcord FC/APC narrow key - FC/PC wide key SM fiber 2m (choose -803 or -804 depending on attenuator connectors)
N4917B-805	Patchcord FC/PC-FC/PC wide key 50 um MM fiber 2 m
N4917B-806	Patchcord FC/APC narrow key -FC/PC wide key 50 um MM fiber 2 m
N4917B-807	Cable assembly coaxial 50 Ω SMA (male) SMA (male) (1 required if using DCA-M, 2 required if using DCA-X)
N4917B-808	Adapter coaxial N type (male) to BNC (female) adapter (choose only if N5171B SI source)
N4910A	Matched cable pair, 2.4 mm (male), 0.85 m
N9398F	DC block 50 kHz - 50 GHz, 2.4 mm (male). (For unused M8061A/2A data output)
85138A	Coaxial termination 50 Ω DC - 50 GHz, 2.4 mm (male). (For unused M8062A data output)
11636B	Power splitter DC - 26.5 GHz (choose only if using DCA-X)
83059A	Coaxial adapter 3.5 mm (male) to 3.5 mm (male) (choose only if using DCA-X)
82357B	USB/GPIB interface
10833A	GPIB cable, 1 m (choose quantity)

Keysight Related Literature

Related Keysight literature	Pub. No.
Improving the Accuracy of Optical Transceiver Extinction Ratio Measurements	5989-2602EN
J-BERT M8020A High-Performance BERT Data Sheet	5991-3647EN
Pulse Function Arbitrary Noise Generators Data Sheet	5989-6433EN
8160xx Family of Tunable Laser Sources Data Sheet	5989-7321EN
81490A Reference Transmitter Data Sheet	5989-7326EN
8157xA Optical Attenuators Data Sheet	5988-2696EN
N77-Series Attenuators Data Sheet	5990-4394EN
Infiniium DCA-X 86100D Wide-Bandwidth Oscilloscope Mainframe and Modules Data Sheet	5990-5824EN
N1090A, N1092A/B/C/D/E and N1094A/B DCA-M Optical and Electrical Sampling Oscilloscopes Data Sheet	5992-1454EN
N1076A, N1077A Electrical and Optical Clock Data Recovery Solutions Data Sheet	5992-1620EN

Evolving

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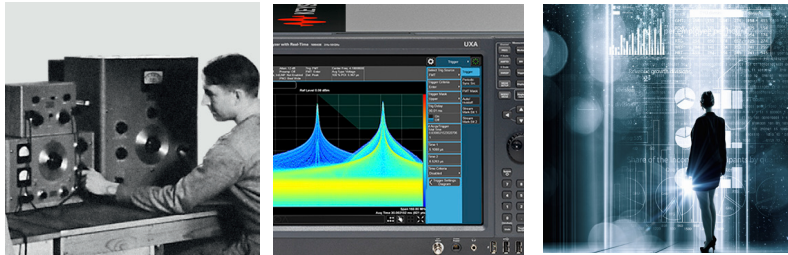
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Three-Year Warranty
www.keysight.com/find/ThreeYearWarranty
Keysight's committed to superior product quality and lower total cost of ownership. Keysight is the only test and measurement company with three-year warranty standard on all instruments, worldwide. And, we provide a one-year warranty on many accessories, calibration devices, systems and custom products.

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