

# Keysight N4391B Optical Modulation Analyzer

## General Information

The Keysight N4391B Optical Modulation Analyzer enables development of the coherent technologies required to achieve the next level of performance in modern communication systems such as between, and in, datacenters. It consists of a UXR real-time oscilloscope and a calibrated coherent optical receiver. The N4391B builds on the UXR oscilloscope series' noise performance and Keysight's well-known, reliable, and flexible vector signal analysis (VSA) software.

The most compact OMA solution of its class, the N4391B not only solves your coherent measurement problems but also makes your test equipment decision easier and protects your investment: it provides two paths of upgradability that can be accomplished in minutes through the installation of licenses.

While complex modulated signals are commonly used in long-distance transmission across DWDM links, newly proposed technologies for intra-datacenter interconnect use the coherent approach in the O-band, addressing the higher data rate need with improved power efficiency. Keysight now provides OMA coherent receivers for the O-band in addition to the current coherent receivers that work in the C-band and L-band.



# Applications

The ever-growing demand for higher transmission capability drives symbol rates on an ever-increasing trajectory. Yesterday's systems at 64 GBaud are yielding to newly proposed ones at 124 GBaud and beyond to 200 GBaud. The Keysight N4391B helps you keep pace with this evolution that demands test equipment that can handle the symbol rate classes of transceivers for 800 Gb/s, 1.2 Tb/s to 1.6 Tb/s, from the first day in advanced research through the development phase.

Not only symbol rates are challenging, but also modulation formats are getting more demanding due to the higher-order quadrature amplitude modulation which requires a step up in noise performance. The N4391B meets this challenge with the UXR's Effective Number of Bits performance having an ENOB of 5.4. The N4391B, based on the latest UXR Oscilloscope series, is the best-suited optical modulation analyzer to support these application requirements.

The Keysight N4391B provides an operating bandwidth up to 110 GHz and a myriad of options for selecting modulation formats. Even user-defined modulation formats are supported through an additional option, and all at an outstanding high ENOB at highest bandwidths.

# Product Details

The N4391B is offered with two versions of optical coherent receivers: one is calibrated to 70 GHz operation and equipped with 1.85 mm connectors. It includes C-band and O-band variants. A second one is factory calibrated to 110 GHz and equipped with 1.0 mm connectors. The bandwidth of operation is dependent on the oscilloscope bandwidth and the coherent receiver bandwidth chosen.

In each C-band configuration, the optical coherent receiver is comprised of an internal power monitor, internal LO, LO output and external LO input. The O-band version requires an external LO tunable laser operating in the 1.3  $\mu\text{m}$  band.

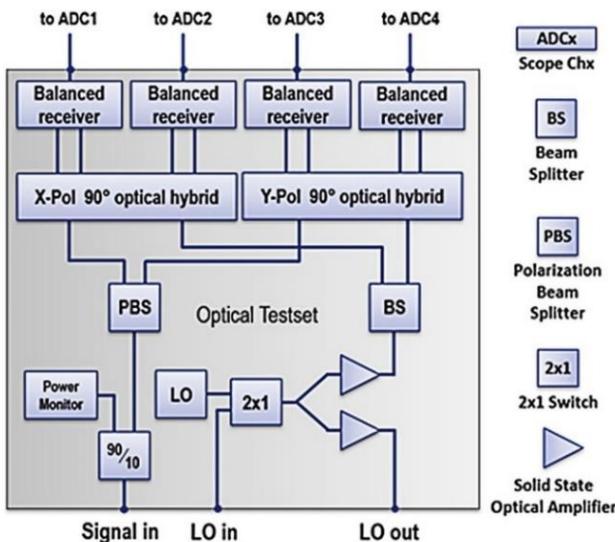


Figure 1. Block diagram of the calibrated coherent optical receiver

## Bandwidth upgradability

Each of the N4391B's configurations are upgradable to higher bandwidths: configurations based on the 1.85 mm connector can be upgraded from 40 GHz to 50 GHz, or 59 GHz, up to 70 GHz, while configurations based on the 1.0 mm connector can be upgraded from 40 GHz to 59 GHz, 70 GHz, 80 GHz, 100 GHz, up to 110 GHz. There are even configurations possible that feature different bandwidths for electrical and optical measurements.

Upgrading the coherent receiver from option 007 to option 011 requires hardware rework at Keysight.

## Turn-key solution

Compared to the time-consuming and resource-intensive implementation of a home-grown optical modulation analysis solution, the fully integrated N4391B provides a fully specified and reliable test instrument that helps greatly reduce time-to-market. With guaranteed and characteristic specifications right out of the box, Keysight takes responsibility for accurate and reliable test results which can only be achieved with a turn-key solution.

## On-site verification and re-calibration function

The on-site verification and re-calibration function contained in the OMA software enables to verify the performance of a N4391B system and to apply adjustments if necessary. Calibrating the system in its operating environment maximizes system performance and minimizes down-time. Assuming a current oscilloscope calibration, the additionally required equipment comprises a tunable laser source, e.g., N7711A or N7779C, a variable optical attenuator, e.g., N7752C or N7764C, and a polarization synthesizer, e.g., N7786C. The recommended re-calibration cycle is 1 year.

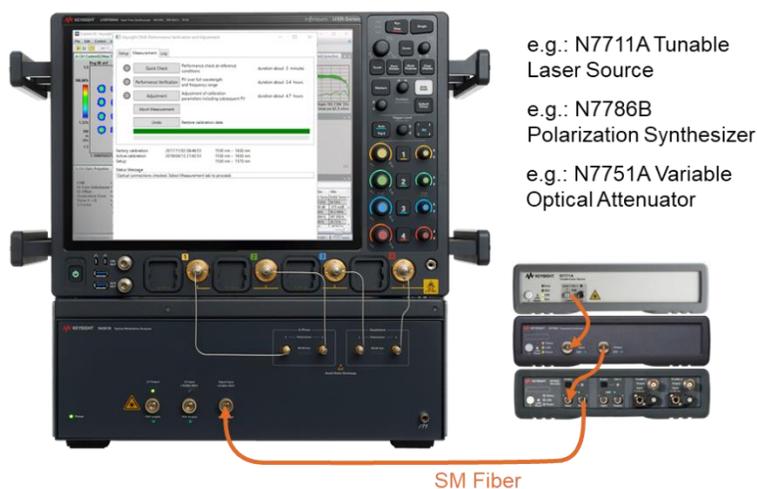


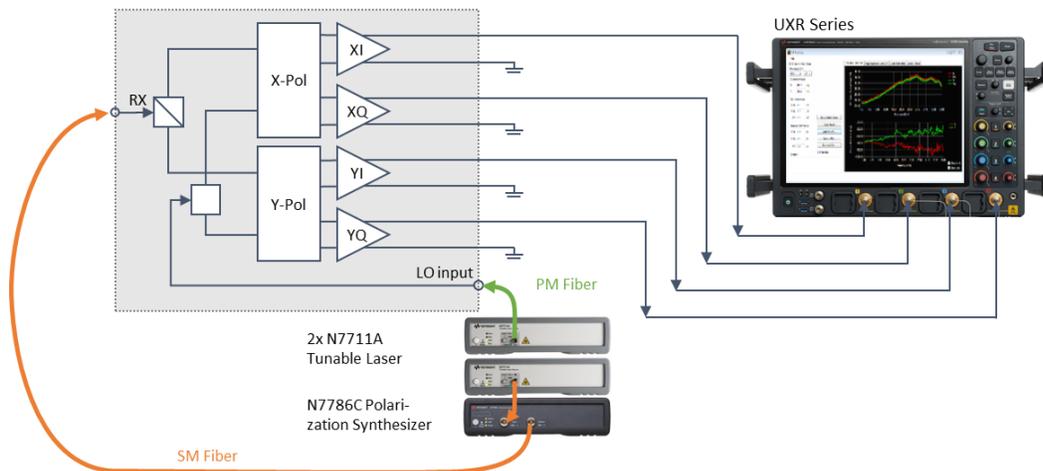
Figure 2. On-site performance verification and adjustment setup

## Integrated Coherent Receiver test

Integrated Coherent Receiver (ICR) modules are key components in coherent transmission systems and are more challenging to test than direct-detection receiver optical sub-assemblies (ROSAs), as the ICRs have phase-sensitive signal detection and provide four electrical outputs and two optical inputs. The test instruments used in ROSA S21 testing cannot be used in a similar way for S-parameter testing of ICRs, making S-parameter testing very challenging.

To help users set up S-parameter tests for ICRs in significantly less time than developing their own solution, the N4391B includes incorporates ICR test software that measures:

- S21 magnitude responses
- IQ skew, XY skew
- IQ angle
- IQ and XY gain imbalance
- EVM noise floor
- Image suppression



**Figure 3.** Test setup for an integrated coherent receiver

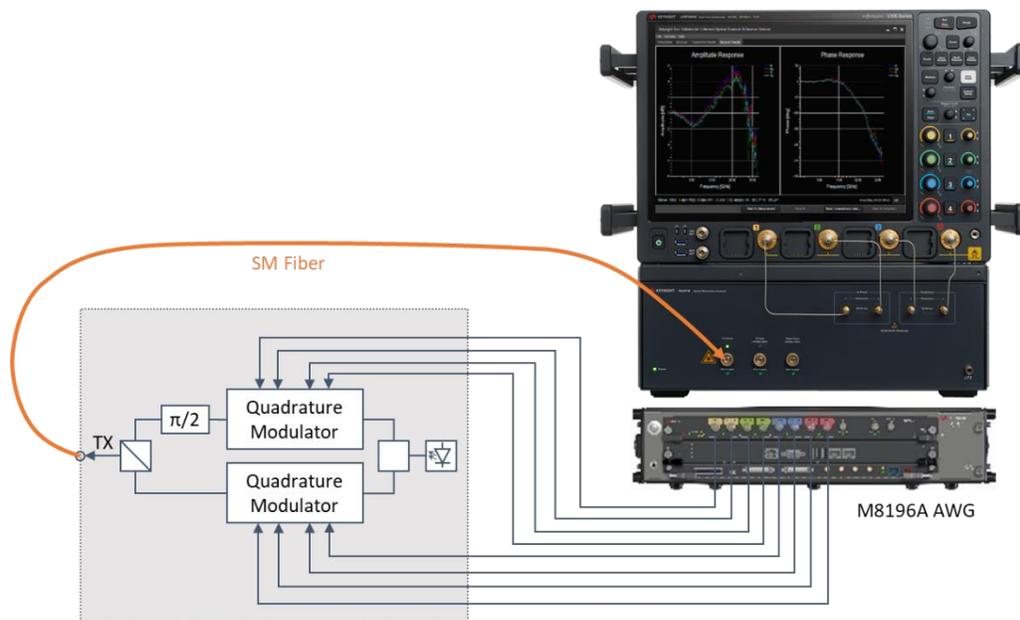
## Coherent optical device test function

Coherent optical devices such as dual-polarization IQ modulators and intradyne coherent receivers need to be tested in their different development stages as well as qualified by the system integrators.

The coherent optical device test function of the OMA software forms a turn-key solution for the characterization of these devices. One user interface provides control of all instruments, i.e., an arbitrary waveform generator (AWG), the OMA, and in case of Rx devices, a polarization synthesizer, through a single software package. With one DUT connection you can get everything done, which saves test time, and reduces the uncertainty introduced by connecting and reconnecting the device. The coherent optical device test function provides:

- S21 magnitude and phase responses
- IQ skew, XY skew

The setup can be customized in three different ways for transmit device testing, receive device testing and sequential testing of both, transmit and receive devices. Furthermore, it can be extended to perform system-level tests as well as wavelength and power calibration of the laser.



**Figure 4.** Test setup for a coherent optical transmitter

# Specifications (Preliminary)

## N4391B system specifications

Specification parameter	N4391B-007, N4391B-E02	N4391B-011
Maximum detectable symbol rate	DC–80 100 118 140 Gbaud <sup>1</sup>	DC–80 118 140 160 200 220 Gbaud <sup>1</sup>
Sample rate	256 GSa/s	
Operating frequency range	DC–40 50 59 70 GHz <sup>1</sup>	DC–40 59 70 80 100 110 GHz <sup>1</sup>
Maximum record length	2 GSa max., 200 MSa standard	
ADC Resolution	10 bits	
Number of 4 channel UXR oscilloscopes	1	
Optical wavelength operating range <sup>4</sup>	1527.60 nm to 1630.0 nm (Option 007) 1270 nm to 1340 nm (Option E02)	1527.60 nm to 1620 nm
Relative skew after correction	< ± 0.5 ps	
Image suppression <sup>2</sup>	> 35 dB	
EVM Noise floor <sup>2</sup>	< 1.6 % at 2.5 GHz < 2.9 % at 10 GHz	
Sensitivity <sup>3</sup>	-20 dBm	

1. Depending on oscilloscope option

2. Valid at the following reference conditions

- Sampling rate 256 GSa/s
- Optical continuous wave signal at optical input port
- Signal power > 0 7.5 dBm, 160 mV range
- Optical frequency is offset by 2.5/10 GHz from local oscillator frequency
- Vector analyzer I-Q spectrum span set to 12.5/40 GHz
- QPSK demodulation
- 10/40 Gbaud symbol rate
- PolStokesAlign set to “Single Polarization”
- KFPhaseTrack with carrier phase variance set to 1E-4
- Result length set to 500 symbols
- Raised cosine filter selected as reference filter
- 25°C ± 5 K environmental temperature

3. Valid at EVM = 32.5% for 32 Gbaud DP-QPSK corresponding to raw BER = 1E-3

4. Access to full wavelength range requires external LO

## Absolute Maximum Ratings

Specification parameter	N4391B-007, N4391B-E02, N4391B-011
Maximum signal input power	+14 dBm
Maximum signal input power damage level	+20 dBm
External local oscillator maximum input power	+20 dBm

# UXR Key Specifications (Preliminary)

For details on the Infiniium UXR-Series Oscilloscopes please refer to data sheet 5992-3132EN.

Specification parameter	UXR0404A, UXR0404AP	UXR0504A	UXR0594A, UXR0594AP	UXR0704A, UXR0704AP
Analog input channels	4	4	4	4
Analog -3 dB bandwidth	40 GHz	50 GHz	59 GHz	70 GHz

Specification parameter	UXR0804A	UXR1004A	UXR1104A
Analog input channels	4	4	4
Analog -3 dB bandwidth	80 GHz	100 GHz	110 GHz

# N4391B Optical Receiver Specifications (Preliminary)

General parameters	N4391B-007	N4391B-E02 <sup>2</sup>	N4391B-011
Analog bandwidth (-3 dB)	> 58 GHz	> 58 GHz	> 90 GHz
Analog bandwidth (-10 dB)	> 70 GHz	> 70 GHz	> 110 GHz
Signal input wavelength range <sup>1</sup>	1527.60 nm to 1630 nm	1270 nm to 1340 nm	1527.60 nm to 1620 nm
Receiver polarization extinction ratio	> 40 dB		
Average input power monitor accuracy	± 0.5 dB		
<b>Internal Local Oscillator (LO) and LO output</b>	<b>N4391B-007, N4391B-011</b>		
Frequency (wavelength) range	1527.6 nm to 1570.0 nm (196.25 THz to 190.95 THz)		
Frequency (wavelength) uncertainty	± 560 MHz (± 4.5 pm), guaranteed ± 310 MHz (± 2.5 pm), typical		
Frequency resolution	100 MHz (0.8 pm at 1550 nm)		
Linewidth	< 100 kHz		
Sidemode suppression ratio	> 50 dB		
RIN	-145 dB/Hz (10 MHz to 40 GHz)		
Wavelength settling time	< 30 s		
Optical CW output power	> +14 dBm		
<b>Local Oscillator input</b>	<b>N4391B-007, N4391B-011</b>	<b>N4391B-E02</b>	
External local oscillator input power range	0 dBm to +14 dBm	0 dBm to +14 dBm	
Small signal gain, external laser input to local oscillator output (-20 dBm LO input power)	Typical 27 dB at 1550 nm	Typical 23 dB at 1310 nm	
Saturation output power at -3 dB compression	+15 dBm		

1. Access to full wavelength range requires external LO.  
2. All specifications are typical.

# General Characteristics (Preliminary)

N4391B-007, N4391B-E02, N4391B-011

Dimensions (wide x height x deep)	
Oscilloscope	43.5 cm (17.1") x 31,1 cm (12.24") x 56.1 cm (22.05")
Optical Coherent Receiver	43.1 cm (17") x 17 cm (6.7") x 55.2 cm (21.7")
Complete Instrument	53 cm (20.9") x 48 cm (18.9") x 55.2 cm (21.8")
Weight	
Oscilloscope	40.8 kg (90 lbs )
Optical Coherent Receiver	11.2 kg (24.7 lbs)
Environmental	
Storage temperature range	-40° C to +70° C
Operating temperature range	+5° C to +35° C
Humidity	15% to 80% relative humidity, non-condensing
Operating altitude	0 to 2000 m
Power	
UXR Oscilloscope voltage	220V AC, 50 to 60 Hz
Power	2615 VA
Optical Receiver voltage	100 to 240V AC, 50 to 60 Hz
Power	300 VA
Safety designed to and tested to	IEC61010-1, UL61010, CSA22.2 61010.1
EMC tested to	IEC61326-1
Warm-up time	30 minutes
Recommended re-calibration interval	1 year

## Explanation of Terms

### Operating frequency range

The operating frequency range is the frequency range of corrected signal spectral components by de-embedding for frequency and phase characteristics of the individual hardware.

### Analog bandwidth

The analog bandwidth describes the 3 dB bandwidth of the full opto-electronic input path without any frequency or phase corrections.

### Sensitivity

The sensitivity limit corresponds to the received signal Power at the input interface for which a 32 GBaud DP-QPSK exhibits an EVM of 32.5% or less. An EVM of 32.5% corresponds to a BER of 1E-3 for assumed added Gaussian white noise (AWGN).

# Ordering Information for New Product

## 1) Configure system setup

N4391B-007	70 GHz Optical Modulation Analyzer Receiver including 1 license for OMA software
N4391B-E02	70 GHz, 1310 nm Optical Modulation Analyzer Receiver including one License for OMA Software, requires O-band Tunable Laser
N4391B-011	110 GHz Optical Modulation Analyzer Receiver incl. 1 license for OMA software
<b>Select one of these UXR oscilloscopes or integration option together with N4391B-007 or N4391B-E02</b>	
N4391B-040	Infiniium UXR0404A Real-Time Oscilloscope, 40 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-050	Infiniium UXR0504A Real-Time Oscilloscope, 50 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-059	Infiniium UXR0594A Real-Time Oscilloscope, 59 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-070	Infiniium UXR0704A Real-Time Oscilloscope, 70 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-011	110 GHz Optical Modulation Analyzer Receiver including 1 license for OMA software
<b>Select one of these UXR oscilloscopes or integration option together with N4391B-011</b>	
N4391B-P40	Infiniium UXR0404AP Real-Time Oscilloscope, 40 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.0 mm
N4391B-P59	Infiniium UXR0594AP Real-Time Oscilloscope, 59 GHz, 256 GSa/s, 4 Ch, 200 MSa/Ch, 1.0 mm
N4391B-P70	Infiniium UXR0704AP Real-Time Oscilloscope, 70 GHz, 256 GSa/s, 4 Ch, 200 MSa/Ch, 1.0 mm
N4391B-080	Infiniium UXR0804A Real-Time Oscilloscope, 80 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.0 mm
N4391B-100	Infiniium UXR1004A Real-Time Oscilloscope, 100 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.0 mm
N4391B-110	Infiniium UXR1104A Real-Time Oscilloscope, 110 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.0 mm
N4391B-M01	Integration of customer owned UXR0804A, UXR1004A or UXR1104A Oscilloscope
<b>Mandatory software</b>	
89601B-200	Basic vector signal analysis and hardware connectivity, transportable license
89601B-AYA	Vector modulation analysis, transportable license
<b>2) Optional software</b>	
89601B-BHF	Custom OFDM modulation analysis
89601B-BHK	Custom IQ modulation analysis
<b>3) Recommended LO laser source for N4391B-E02</b>	
N7779C-113	Step- Tunable Laser Source, High Power and Low SSE, 1240 – 1380 nm

# Ordering Information for Upgrades

## 1) Configure system setup, select one of the two upgrade options

N4391B-UG1 <sup>1</sup>	Upgrade customer's N4391A-110 to N4391B-007 including latest OMA software
N4391B-UG2 <sup>1</sup>	Upgrade customer's N4391A-120 to N4391B-007 including latest OMA software

### Select one of these UXR oscilloscopes or integration option

N4391B-040	Infiniium UXR0804A Real-Time Oscilloscope, 40 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-050	Infiniium UXR1004A Real-Time Oscilloscope, 50 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-059	Infiniium UXR1104A Real-Time Oscilloscope, 59 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-070	Infiniium UXR0704A Real-Time Oscilloscope, 70 GHz, 256 GSa/s, 4Ch, 200 MSa/Ch, 1.85 mm
N4391B-M00	Integration of customer owned UXR0404A, UXR0504A, UXR0594A, or UXR0704A Oscilloscope

## 2) Optional software

89601B-BHF	Custom OFDM modulation analysis
89601B-BHK	Custom IQ modulation analysis

## Optical bandwidth upgrades

N4391BU	Upgrade of N4391B Optical Modulation Analyzer
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### Upgrade licenses applicable to N4391B-007 and N4391B-E02

N4391BU-B04 <sup>2</sup>	Upgrade license for N4391B-040 for Optical Measurements up to 70 GHz
N4391BU-B05 <sup>2</sup>	Upgrade license for N4391B-050 for Optical Measurements up to 70 GHz
N4391BU-B06 <sup>2</sup>	Upgrade license for N4391B-059 for Optical Measurements up to 70 GHz

### Upgrade licenses applicable to N4391B-011

N4391BU-B11 <sup>2</sup>	Upgrade license for N4391B for Optical Measurements up to 110 GHz
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## Hardware upgrades

N4391BU-U20 <sup>3</sup>	Upgrade of N4391B-007 (purchased before Sep 1, 2020) to N4391B-011
N4391BU-U21 <sup>3</sup>	Upgrade of N4391B-007 (purchased after Sep 1, 2020) to N4391B-011

For upgrades from N4391A to N4391B-011 please contact your Keysight representative.

- Software licenses will be transferred to the N4391B system.
- N4391BU-B04/B05/B06/B11 upgrades only the bandwidth available for optical measurements. The bandwidth available for electrical measurements is determined by the Infiniium UXR Real-Time Oscilloscope. N4391BU-B04/B05/B06/B11 prevents measurements with more than 500 MSamples memory depth. With N4391BU-B04/B05/B06/B11, the OMA works only with Keysight lasers for external LO. These must be visible in VISA/connection expert. Otherwise, the bandwidth will fall back to 59 GHz or less, whichever electrical bandwidth is licensed. N4391BU-B04/B05/B06/B11 reduces the measurement update rate significantly.
- Upgrade of optical coherent receiver only. Does not include upgrade of the oscilloscope. Please contact your Keysight representative for details.

# Shipping Content (Preliminary)

	N4391B-007, N4391B-E02	N4391B-011
1 x Oscilloscope depending on ordered option	UXR004A/ UXR0504A/ UXR0594A/ UXR0704A	UXR0404AP/ UXR0594AP/ UXR0704AP/ UXR0804A/ UXR1004A/ UXR1104A
1 x Optical coherent receiver		
4 x Rigid RF cable assembly	1.85 mm (m)	1.0 mm (m)
1 x Optical mouse, USB		
1 x 104 key standard keyboard with USB connector		
1 x Quick start guide (English)		
3 x 81000NI Fiber Connector Adapter FC /APC		
1 x Calibration certificate		
1 x Test Data Sheet		
3 x License Certificates OMA and VSA Software (additional Certificates depending on additional ordered software)		
1 x China RoHS Addendum for Photonic Test and Measurement Products		
1 x Cable-Assembly USB-Plug A TO B 4-COND 0.5 m		
1 x Wrench – 2 mm thick dual		6 and 7 mm
1 x Wrench-Torque	8-in-lb, 5/16 inch	4-in-lb 6 mm
4 x Adapter, Ruggedized Female	1.85 mm	1.0 mm
1 x Wrench-Torque Special Double-end		14 mm-open end 4-in-lb and 10-in-lb
1 x Heel Ground Strap		
1 x ESD MAT Cord		
1 x ESD Warning Sticker Sheet		
1 x China RoHS Addendum for Oscilloscope		
1 x Keysight Safety Leaflet		
1 x Tips for Preventing Damage to Oscilloscopes		
2 x Local Power Cords		

# Optical Instruments Online Information

Optical modulation analyzers

[www.keysight.com/find/oma](http://www.keysight.com/find/oma)

Optical test instruments

[www.keysight.com/find/oct](http://www.keysight.com/find/oct)

Lightwave component analyzers

[www.keysight.com/find/lca](http://www.keysight.com/find/lca)

Polarization solutions

[www.keysight.com/find/pol](http://www.keysight.com/find/pol)

Electro-optical converters

[www.keysight.com/find/ref](http://www.keysight.com/find/ref)

Optical test instruments accessories

[www.keysight.com/comms/oct-accessories](http://www.keysight.com/comms/oct-accessories)

Keysight photonic discussion forum

[www.keysight.com/find/photonic\\_forum](http://www.keysight.com/find/photonic_forum)

# Confidently Covered by Keysight Services

Prevent delays caused by technical questions, or system downtime due to instrument maintenance and repairs with Keysight Services. Keysight Services are here to support your test needs with expert technical support, instrument repair and calibration, software support, training, alternative acquisition program options, and more.

A KeysightCare agreement provides dedicated, proactive support through a single point of contact for instruments, software, and solutions. KeysightCare covers an extensive group of instruments, application software, and solutions and ensures optimal uptime, faster response, faster access to experts, and faster resolution.

## Keysight Services

Offering	Benefits
<b>KeysightCare</b> 	KeysightCare provides elevated support for Keysight instruments and software, with access to technical support experts that respond within a specified time and ensure committed repair and calibration turnaround times (TAT). KeysightCare offers multiple service agreement tiers, including KeysightCare Assured, Enhanced, and Application Software Support. See the <a href="#">KeysightCare data sheet</a> for details.
KeysightCare Assured	KeysightCare Assured goes beyond basic warranty with repair services that include committed TAT and unlimited access to technical experts.
KeysightCare Enhanced	KeysightCare Enhanced includes all the benefits of KeysightCare Assured plus Keysight's accurate and reliable calibration services, accelerated, and committed TAT, and technical response.
<b>Keysight Support Portal &amp; Knowledge Center</b>	All KeysightCare tiers include access to the Keysight Support Portal where you can manage support and service resources related to your assets such as service requests, and status, or browse the Knowledge Center.
<b>Education Services</b>	Build confidence and gain new skills to make accurate measurements, with flexible Education Services developed by Keysight experts. Including Start-up Assistance.
<b>Alternative acquisition options</b>	
<b>KeysightAccess</b>	Reduce budget challenges with a subscription service enabling you to get the instruments, software, and technical support you want for your test needs.

## Recommended services

Maximize your test system up-time by securing technical support, repair, and calibration services with committed response and turnaround times. 1-year KeysightCare Assured is included in every new instrument purchase. Obtain multi-year KeysightCare upfront to eliminate the need for lengthy and tedious paperwork and yearly requests for maintenance budget. Plus, you benefit from secured service for 2, 3, or 5 years.

Service	Function
<b>KeysightCare Enhanced*</b>	<b>Includes tech support, warranty and calibration</b>
R-55B-001-1	KeysightCare Enhanced – Upgrade 1 year
R-55B-001-2	KeysightCare Enhanced – Extend to 2 years
R-55B-001-3	KeysightCare Enhanced – Extend to 3 years (Recommended)
R-55B-001-5	KeysightCare Enhanced – Extend to 5 years (Recommended)
<b>KeysightCare Assured</b>	<b>Includes tech support and warranty</b>
R-55A-001-2	KeysightCare Assured – Extend to 2 years
R-55A-001-3	KeysightCare Assured – Extend to 3 years
R-55A-001-5	KeysightCare Assured – Extend to 5 years
<b>Start-Up Assistance</b>	
PS-S10	Included – instrument fundamentals and operations starter
PS-S20	Optional, technology & measurement science standard learning

\* Available in select countries. For details, please view the [datasheet](#). R-55B-001-2/3/5 must be ordered with R-55B-001-1.

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at [www.keysight.com](http://www.keysight.com).



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