

# N7004A/N7005A

## Optical-to-Electrical Converter for Infiniium Realtime Oscilloscopes

### Fully-integrated Optical Front-end Solutions for Infiniium Real-time Oscilloscope

#### N7004A characteristics

- DC to 33 GHz typical (-3 dBe, electrical)
- Single-mode and multimode inputs
- 50/125  $\mu\text{m}$ , 750 nm to 1650 nm (covers main wavelengths: 850 nm, 1310 nm, and 1550 nm)
- Designed for reference receiver testing of industry optical standards or characterizing raw response of an optical transmitter
- Optical measurement features built into the Infiniium baseline software version 05.70 or higher
- Compatible with Infiniium UXR, V-Series, 90000 X-Series, Z-Series and discontinued 90000 Q-Series real-time oscilloscopes

#### N7005A characteristics

- DC to 60 GHz typical (-3 dBe, electrical)
- Single-mode input
- 9/125  $\mu\text{m}$ , 1250 nm to 1600 nm (covers main wavelengths: 1310 nm, and 1550 nm)
- FlexDCA SW supports PAM4 measurement capabilities such as TDECQ for Infiniium UXR oscilloscopes and N7005A
- Optical measurement features built into the Infiniium UXR baseline software version 10.25 or higher
- Compatible with Infiniium UXR oscilloscope with  $\geq 40$  GHz bandwidth

The Keysight N7004A and N7005A optical-to-electrical converter is a high-sensitivity DC-coupled photodetector module designed for direct optical-to-electrical conversion of optical telecommunication or data communication signals into an Infiniium real-time oscilloscope. Each N7004A or N7005A adapter contains a measured S-parameter for an optimized correction filter, and this frequency response data is used to flatten the frequency response for a more accurate measurement.

Traditionally, the sampling oscilloscope has been the tool of choice for viewing and measuring optical signals with oscilloscopes. Sampling oscilloscopes provide a myriad of benefits in measuring optical signals with an optimized reference receiver, low noise/jitter, and various measurement features optimized to characterize optical signals. On the other hand, real-time oscilloscopes have been preferred for ample debug/troubleshooting capabilities and the ability to capture intermittent single-shot events with deep memory and fast sample rates.



Figure 1. The N7004A 33 GHz O/E converter (left) and the N7005A 60 GHz O/E converter (right) for Infiniium real-time oscilloscopes

### N7004A – 33 GHz O/E converter

The N7004A is the first fully-integrated optical-to-electrical converter solution for Infiniium real-time oscilloscopes. A full suite of optical measurement software is built into the Infiniium baseline software v 05.70 and is offered at no additional cost. The N7004A comes in a compact form factor that is plugged directly into the AutoProbe II probe interface of the Infiniium oscilloscope.



Figure 2. The N7004A comes in a compact form factor that is plugged directly into the AutoProbe II probe interface of the Infiniium oscilloscope.

The adapter provides electrical bandwidth ranging from DC to 33 GHz. When used with an Infiniium V-Series, Z-Series or UXR 33 GHz oscilloscope, the N7004A allows users to view optical streams at speeds up to 28 Gbps, making this the ideal solution for characterizing or troubleshooting high-speed optical signals in system level testing. The N7004A with an Infiniium real-time oscilloscope is the ideal solution for users who want to see the unfiltered response of optical transmissions as well.

The input is a 50  $\mu\text{m}$ /125  $\mu\text{m}$  fiber that can be used with a 9  $\mu\text{m}$  single-mode fiber or a 50  $\mu\text{m}$  multimode fiber at wavelengths from 750 to 1650 nm, and also has a FC/PC adaptor. The reference receiver measurement is made with a built-in 4<sup>th</sup> order Bessel Thomson software filter that allows the waveform to be viewed similarly to what an optical receiver in an actual communication system would display. The 4<sup>th</sup> order Bessel Thomson filter bandwidth is limited to 2/3 of the Brickwall bandwidth of the oscilloscope. For a 33 GHz oscilloscope with the Bessel Thomson filter on, this yields a 22 GHz Bessel Thomson filter, which covers 28 Gbps x 0.75 = 21 GHz.

### N7005A – 60 GHz O/E converter

The N7005A is a 60 GHz (-3 dB, Brickwall) O/E converter compatible with the Keysight UXR oscilloscope with a 1.85 mm or 1 mm input. The frequency response of a DSP corrected N7005A is either flat to up to 60 GHz Brickwall response or follows a 4<sup>th</sup> order Bessel Thomson response until it hits the Brickwall at 70 GHz. The N7005A used in conjunction with the 70 GHz Infiniium UXR oscilloscope supports a 4<sup>th</sup> order Bessel Thomson response to view optical streams at speeds up to 56 Gbaud PAM4, making this the ideal solution for characterizing or troubleshooting high-speed optical signals in system level testing and debugging.

Infiniium UXR baseline software v 10.25 or higher covers basic optical measurement features and dark calibration. The FlexRT measurement software installed on Infiniium UXR oscilloscope supports deep analysis of PAM4 signaling measurement capabilities such as TDECQ.



Figure 3. N7005A 60 GHz O/E converter.

### FlexRT measurement SW controls the UXR-based oscilloscope equipped with N7005A O/E

The N1010100A R&D Package and N1010200A Manufacturing Package can control a UXR-based oscilloscope and the N7005A using a FlexDCA software feature called FlexRT (real-time oscilloscope control). FlexDCA is the same software used to control Keysight's N1092A/B/C/D Digital Communication Analyzer (DCA-M), which is well-known for performing fast and accurate optical PAM4 measurements, such as TDECQ.

Using the same SW application to control both the DCA-based and UXR-based oscilloscopes ensures optimal measurement correlation while providing the same UI experience for maximum ease-of-use. The FlexRT feature controls the real-time acquisition system to provide calibrated optical measurements such as:

- Transmitter and Dispersion Eye Closure Quaternary (TDECQ)
- Outer Optical Modulation Amplitude (Outer OMA)
- Outer Extinction Ratio (Outer ER)
- Average Optical Power
- And more...

The integrated SW yields optimal throughput while making it easy for the user to configure the clock recovery, channel, and reference receiver settings required to perform compliant optical measurements.

## Optical and Electrical Characteristics and Specifications

	N7004A	N7005A
Bandwidth, typical (electrical, -3 dBe)	33 GHz (with Brickwall filter)	60 GHz (with Brickwall filter)
	22 GHz (with 4 <sup>th</sup> order Bessel Thomson filter)	46.6 GHz (with 4 <sup>th</sup> order Bessel Thomson filter)
Bandwidth, warranted (electrical, -3 dBe)	32 GHz (with Brickwall filter)	
	21.3 GHz (with 4 <sup>th</sup> order Bessel Thomson filter)	
Rise time (10 to 90%), typical	13.3 psec (with Brickwall filter)	7.3 psec (with Brickwall filter)
	17.7 psec (with 4 <sup>th</sup> order Bessel Thomson filter)	8.4 psec (with 4 <sup>th</sup> order Bessel Thomson filter)
Rise time (20 to 80%), typical	9.4 psec (with Brickwall filter)	5.2 psec (with Brickwall filter)
	12.3 psec (with 4 <sup>th</sup> order Bessel Thomson filter)	5.8 psec (with 4 <sup>th</sup> order Bessel Thomson filter)
Optical output coupling	DC	
Wavelength range	750 to 1650 nm	1250 to 1600 nm
RMS noise ( $\mu$ W)	See the noise characteristics table	
Conversion gain (V/W)	850 nm MM: 68 (min), 75 (typical)	
	1310 nm MM/SM: 105 (min), 110 (typical)	1310 nm SM: 85 (min), 93 (typical)
	1550 nm SM: 105 (min), 110 (typical)	1550 nm SM: 72 (min), 85 (typical)
Maximum linear input power	4 mW	
Maximum non-destructive input power	8 mW	
Input return loss (dB)	850 nm MM: -17 (typical), -15 (max) (fully filled fiber)	
	1310 nm SM: -18.5 (typical), -16 (max)	1310 nm SM: -25 (max)
	1550 nm SM: -14 (typical)	1550 nm SM: -25 (max)
Input connector type	FC/PC to 50/125 $\mu$ m fiber, compatible with single-mode or multimode fiber	FC/PC to 9/125 $\mu$ m fiber, compatible with single-mode fiber
Output connector type	2.92 mm female	1.85 mm male

	N7004A	N7005A
Infiniium software features	Optical measurements in watts, extinction ratio with dark calibration, eye mask testing (including ability to load DCA masks with margin and user defined mask support), power of 1 and 0, optical modulation amplitude, average power, remote command support for all new features	
Oscilloscope compatibility	Infiniium UXR, V, 90000X, Z series and discontinued 90000 Q series	Infiniium UXR with 40 GHz or higher
Oscilloscope software compatibility	Infiniium software version 05.70 or higher for Infiniium non-UXR  Infiniium software version 10.25.00702 or higher for UXR models	Infiniium software version 10.25.00702 for UXR models



Figure 3. A full suite of optical measurement software is built into the Infiniium baseline software.





Figure 4. The N7004A used with an Infiniium real-time oscilloscope offers user-selectable hardware Brickwall filter and 4th order Bessel Thomson filter, making the system ideal for reference receiver testing of industry standards or characterizing raw response of optical transmitters.

## Noise Characteristics

N7004A - Displayed noise on Infiniium 33 GHz V/Z/Q Series scope ( $\mu\text{Wrms}$ )

Wavelength	Filter	Bandwidth	50 $\mu\text{W}/\text{div}$	100 $\mu\text{W}/\text{div}$	200 $\mu\text{W}/\text{div}$	500 $\mu\text{W}/\text{div}$	1 mW/div
1550 nm	Brickwall	33 GHz	7.5	7.7	12.4	32.8	61.4
	Brickwall	25 GHz	5	5.5	8.8	22.6	42.6
	Brickwall	20 GHz	4	4.6	7.2	18.1	34.2
	4 <sup>th</sup> order BT	21 GHz	5.1	5.5	8.6	18.7	41.6
	4 <sup>th</sup> order BT	7.5 GHz	2.7	3.1	4.5	10.7	20.6
1310 nm	Brickwall	33 GHz	6.6	7.2	11.7	31	58.2
	Brickwall	25 GHz	4.5	5.2	8.4	21.6	41.1
	Brickwall	20 GHz	3.6	4.3	6.8	17.2	33.2
	4 <sup>th</sup> order BT	21 GHz	4.3	4.9	8	20.6	39
	4 <sup>th</sup> order BT	7.5 GHz	2.3	2.7	4.2	10.3	19.8
850 nm	Brickwall	33 GHz	11.1	10.7	16	30.1	57
	Brickwall	20 GHz	5.9	6.1	8.7	17.2	32.1
	Brickwall	10 GHz	4.1	4.3	5.9	11.5	21.4
	4 <sup>th</sup> order BT	21 GHz	7.4	7.4	9	20.2	37.8
	4 <sup>th</sup> order BT	7.5 GHz	4	4.2	5.3	10.6	19.6
	4 <sup>th</sup> order BT	3.8 GHz	3.2	3.3	4.1	7.7	14.1

Note 1:

- 21 GHz BT is for 28 Gbps compliance
- 7.5 GHz BT is for 10 Gbps compliance
- 3.8 GHz BT is for 5 Gbps compliance

Note 2:

- Conversion gain at 1550 nm = 120.8 V/W, 1310 nm = 142 V/W, 850 nm = 80.7 V/W



## N7004A - Displayed noise on Infiniium 33 GHz UXR scope ( $\mu\text{Wrms}$ )

Wavelength	Filter	Bandwidth	50 $\mu\text{W}/\text{div}$	100 $\mu\text{W}/\text{div}$	200 $\mu\text{W}/\text{div}$	500 $\mu\text{W}/\text{div}$	1 mW/div
1550 nm	Brickwall	33 GHz	5.3	6.53	9.64	20.8	41.5
	Brickwall	25 GHz	3.89	4.48	6.41	13.5	25.5
	Brickwall	20 GHz	3.26	3.76	5.27	11	20.6
	4 <sup>th</sup> order BT	21 GHz	3.7	4.42	6.34	13.5	25.8
	4 <sup>th</sup> order BT	7.5 GHz	2.31	2.59	3.44	6.96	12.9
	4 <sup>th</sup> order BT	3.8 GHz	1.9	2.09	2.69	3.21	10.1
1310 nm	Brickwall	33 GHz	5.01	6.08	9.25	20.9	40.2
	Brickwall	25 GHz	3.62	4.22	6.16	13.4	25.7
	Brickwall	20 GHz	3.09	3.53	5.07	10.9	20.9
	4 <sup>th</sup> order BT	21 GHz	3.51	4.14	6.13	13.5	25.9
	4 <sup>th</sup> order BT	7.5 GHz	2.13	2.4	3.32	6.9	13.1
	4 <sup>th</sup> order BT	3.8 GHz	1.77	1.95	2.61	5.22	9.85
850 nm	Brickwall	33 GHz	7.64	8.66	10.9	20.1	37.4
	Brickwall	25 GHz	5.75	6.42	7.77	13.5	24.8
	Brickwall	20 GHz	4.99	5.48	6.54	11.2	20.5
	4 <sup>th</sup> order BT	21 GHz	5.57	6.19	7.58	13.4	24.8
	4 <sup>th</sup> order BT	7.5 GHz	3.62	3.86	4.46	7.35	13.2
	4 <sup>th</sup> order BT	3.8 GHz	3.02	3.18	3.61	5.75	10.2

Note 1:

- 21 GHz BT is for 28 Gbps compliance
- 7.5 GHz BT is for 10 Gbps compliance
- 3.8 GHz BT is for 5 Gbps compliance

Note 2:

- Conversion gain at 1550 nm = 129 V/W, 1310 nm = 144 V/W, 850 nm = 83.5 V/W

N7005A - Displayed noise on Infiniium 70 GHz UXR scope ( $\mu\text{Wrms}$ ), at 20  $\mu\text{W/div}$

Filter	Bandwidth	1310 nm	1550 nm
Brickwall	60 GHz	11.03	12.43
4 <sup>th</sup> order BT	12.6 GHz	4.52	5.08
4 <sup>th</sup> order BT	29.5 GHz	7.2	8.12

## Environmental Characteristics

		N7004A	N7005A
Temperature	Operating	+10 to +40 °C (-50 to +104 °F)	+10 to +55 °C (-50 to +131 °F)
	Non-operating	-40 to +70 °C (-40 to +158 °F)	-40 to +70 °C (-40 to +158 °F)
Humidity		80% for temperatures up to 31 °C (87.8 °F) decreasing linearly to 50% relative humidity at 40 °C (104 °F)	

## Mechanical Information

	N7004A	N7005A
Net weight	350 g (0.77 lbs)	410 g (0.9 lbs)
Dimension (W x H x D)	50 mm x 60 mm x 140 mm	

## How Much of Oscilloscope Bandwidth Is Needed?

For NRZ (PAM2):

- Scope BW  $\geq$  Optical data rates in Gbps \* 0.75 \* 3/2

Optical data rates	Reference receiver BT BW (=0.75 x data rate)	Needed scope BW (=3/2 of reference receiver BW)	Recommended scope BW
28 Gbps	21 GHz	> 31.5 GHz	40 GHz (UXR 40 GHz with N7005A) Or 33 GHz (V series 33 GHz with N7004A)

For PAM4:

- Scope BW  $\geq$  Optical symbol rates in Gbaud \* 0.5 \* 3/2

Optical data rates	Optical symbol rates	Reference receiver BT BW (=0.5 x symbol rate)	Needed scope BW (=3/2 of reference receiver BW)	Recommended scope BW
56 Gbps	28 Gbaud	14 GHz	> 21 GHz	40 GHz (UXR 40 GHz with N7005A)
112 Gbps	56 Gbaud	28 GHz	> 42 GHz	70 GHz (UXR 70 GHz with N7005A)

## Ordering Information

Model numbers	Descriptions	Standard accessories
N7004A	33 GHz Optical-to-electrical converter for Infiniium realtime scopes	1x optical-to-electrical converter module, 2x Fiber optic FS/FC-A1 connector, 2x FC dust cap and 1x carrying case
N7005A	60 GHz Optical-to-electrical converter for Infiniium realtime scopes	1x optical-to-electrical converter module, 2x Fiber optic FS/FC-A1 connector, 2x FC dust cap and 1x carrying case
N1010100A	Research and Development package for FlexDCA sampling oscilloscope software	
N1010200A	Manufacturing package for FlexDCA sampling oscilloscope software	

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