USER'S GUIDE

Large-Area Photoreceivers

Models 2031, 2032, 2033, & 2034

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Operation

Introduction

The Model 203X is a general-purpose, battery-powered photoreceiver with a large-area photodetector. There are four versions of the Model 203X receiver, each based on a different photodetector:

Model	Wavelength	Type	Diam.
2031	400–1070 nm	silicon	8 mm
2032	190–1100 nm	UV-enhanced silicon	5.8 mm
2033	800–1750 nm	germanium	5 mm
2034	800–2200 nm	extended-λ InGaAs	1 mm

Note: *Complete specifications for the Model 203X large-area photoreceivers begin on page 23.*

The large area of the photodetector makes it easy to couple light from a variety of sources (including diode lasers, broadband sources, and light from optical fibers) onto the detector without requiring precise optical alignment or focusing. Figures 1 and 2 on the following page show the typical responsivity curves for the different detectors.

Figure 1: Typical responsivities of the Model 2031 & 2033 photodiodes

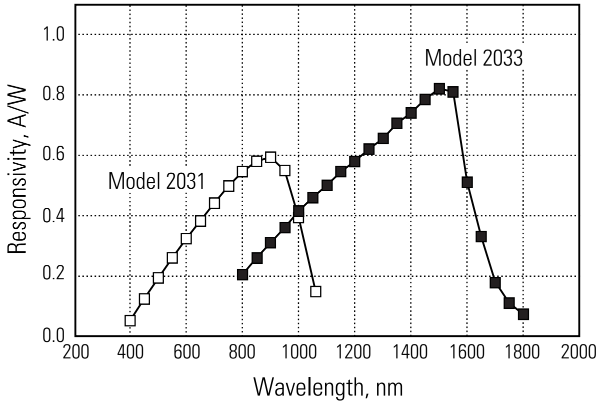
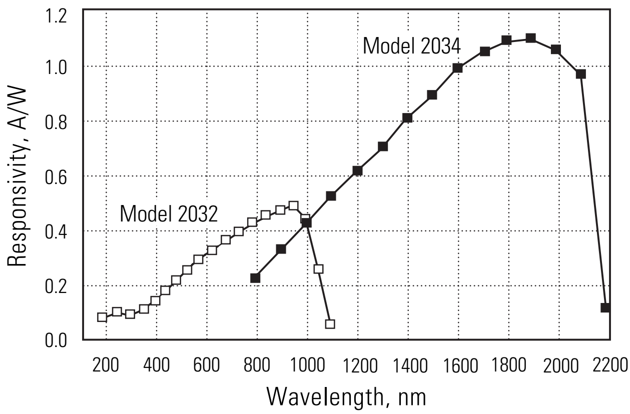


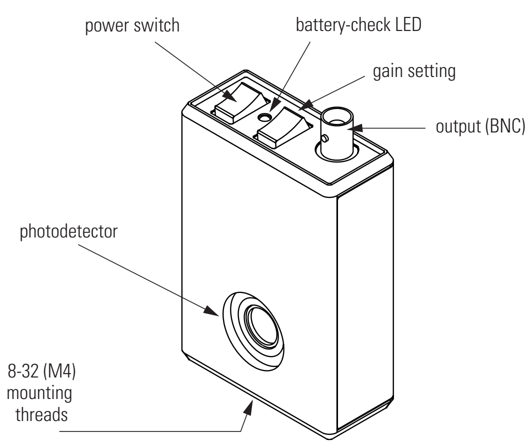
Figure 2: Typical responsivities of the Model 2032 & 2034 photodiodes



Note: *For more information on frequency response and noise, see page 13.*

The photoreceiver's slim casing, shown on the next page, makes it easy to position it in a set-up between closely spaced optics. The switches and BNC output connector are located on top of the receiver for easy access.

Figure 3: The Model 203X casing



Note: *A full mechanical diagram of the Model 203X casing is available on page 23.*

Using the Photoreceiver

1. **Check the battery voltage.** The Model 203X is powered by a single 9-volt alkaline battery. To check the battery condition, push the red power switch to the BATT CHK position. If the green LED lights up, the battery is in good condition; if the LED does not light, the battery needs to be replaced (see page 8).

2. **Mount the photoreceiver.** Use the 8-32 thread (M4 for metric versions) on the bottom of the casing to mount the photoreceiver to a post or pedestal.

   CAUTION! *The threading is seated in a non-conductive plastic pad to reduce the electrical noise associated with ground loops. Be careful not to over-tighten when attaching the casing to a post or pedestal, or the threaded insert can strip out of the plastic pad.*

3. **Connect the receiver output.** Connect your voltmeter, oscilloscope, or other instrument to the Output BNC connector on top of the receiver.

4. **Turn the power switch to "on."** The output voltage should register on your scope or instrument.
5. **Align an optical beam onto the detector.** Be careful to keep the optical power under the maximum optical power of 10 mW to avoid damaging the photodetector.
6. **Adjust the gain.** Use the black switch on top of the receiver to set the gain to low, medium, or high. The bandwidths vary with the gain setting (the label on the front of the photoreceiver indicates the gain and bandwidth values).
7. **Turn the receiver off.** When you are finished with the receiver, return the power switch to the "off" position.

Checking the Battery

The Model 203X is powered by a single, standard 9-volt alkaline battery. Under normal operating conditions with low light levels and a high impedance load attached to the BNC connector, the photoreceiver draws about 1 mA from the battery, and the battery lifetime is approximately 500 hours.

To check the condition of the battery, push the red power switch to the BATT CHK position. If the green LED lights up, the battery is in good condition.

When the battery voltage falls below about 6.5 volts, the green LED will not light up, and the battery should be replaced.

Replacing the Battery

1. Turn the red power switch to "off" to prevent damage to the receiver.
2. Remove the screw on the back of the photoreceiver casing and remove the back cover.

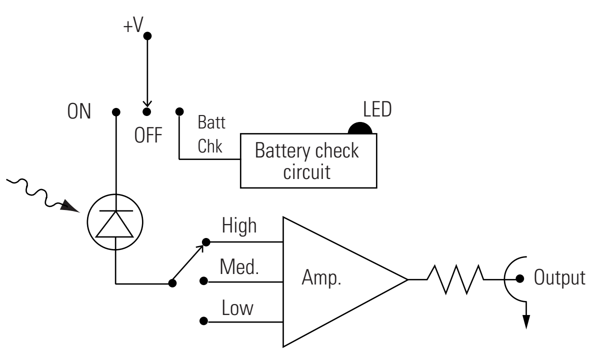
3. Unplug the old battery by rotating it away from the circuit board about the snap-on terminal contacts
4. Install a new 9-volt alkaline battery.
5. Reinstall the back cover and screw.
6. Test the new battery's status by pushing the power switch to the BATT CHK position.

General Features & Principles

Photoreceiver Circuitry

The circuitry inside the Model 203X consists of a photodiode followed by an electronic gain stage. The black switch on top of the casing allows you to select one of three gain settings: low ($2x10^3$ V/A), medium (10^5 V/A), and high ($2x10^6$ V/A). The label on the front of the casing lists the gain and bandwidth values for each of these three gain settings. The amplifier design is optimized so it consumes a minimum of power and generates a minimum of noise at each of the gain settings. A simplified schematic of the Model 203X circuitry is shown in Figure 4.

Figure 4: Functional schematic of the Model 203X circuitry



Optical Power and Output Voltage

The typical operating range for these receivers is from a few nanowatts up to 2 to 5 mW (depending the model and gain setting). Be careful to keep the optical power under the maximum optical power of 10 mW to avoid damaging the photodetector.

To compute the approximate output voltage for a given input optical power use the relationship

$$V_{out} = P_{in} \cdot R \cdot G,$$

where P_{in} is the input optical power in watts, R is the photodetector's responsivity in A/W (see page 6 for typical responsivities), and G is the amplifier's trans-impedance gain in V/A.

For example, the Model 2031 on the medium gain setting and with 10 µW of optical power at 900 nm will have an output voltage of approximately $(10\ \mu W) \cdot (0.6\ A/W) \cdot (10^5\ V/A) = 0.6\ V$.

The maximum optical power that can be detected by the photoreceiver is determined by the input optical power at which the transimpedance gain stage saturates. We can calculate the saturation power at 900 nm for the Model 2031 assuming a maximum output voltage of 5 volts. (The output can typically generate greater than 5 volts, depending on the age of the battery, but to be conservative we assume a maximum output of 5 volts.)

Using the expression $5\ V = P_{sat} \cdot R \cdot G$, the Model 2031 has a saturation power of 4 mW for the low gain setting, 83 µW for the medium gain setting, and 4 µW for the high gain setting. At other wavelengths where the responsivity is lower, the saturation power increases inversely with responsivity.

Frequency Response and Noise

Measuring Bandwidth

The frequency response and noise characteristics of the large-area photoreceiver depend on the selected gain. Figures 5–8 on the following pages give the typical frequency response and noise behavior for the photoreceivers at each of the three gain settings—low, medium, and high. The frequency response of the transimpedance gain is plotted using the expression

$$20 \cdot \log[\mathrm{Gain}(f)/\mathrm{Gain}(0)],$$

where f is the frequency and Gain(0) is the gain at DC. The photoreceiver's bandwidth is defined as the frequency where the gain has decreased by 3 dB, or a factor of $\sqrt{2}$.

Measuring Noise

The photoreceiver noise is characterized using the noise equivalent power (NEP), which is a measure of the weakest optical signal that the photoreceiver can detect. The NEP is the optical power which will produce a signal-to-noise ratio of 1 in a 1-Hz bandwidth. The minimum detectable optical power can be found using the relationship

$$\text{Minimum Optical Power} = NEP \cdot \sqrt{BW},$$

where BW is the bandwidth. Note that NEP is a wavelength-dependent quantity that changes with the photodetector's responsivity.

Another way to characterize the noise is with the photocurrent noise (I_n), which is related to NEP by

$$I_n = R \cdot NEP,$$

where R is the photodetector's responsivity. The photocurrent noise is independent of wavelength because it gives the photoreceiver's noise with the photodetector's responsivity factored out.

To characterize the noise of the large-area photoreceiver, the output electrical noise spectrum is measured with a spectrum analyzer. This voltage noise spectrum is converted to an equivalent optical photocurrent noise by dividing the voltage noise by the transimpedance gain (V/A). The photocurrent noise, $I_n(f)$, has units of pA/$\sqrt{Hz}$ and is plotted in Figures 5–8 using the expression 20·log[$I_n(f)$/1 A].

Calculating NEP

The noise equivalent power (NEP) can be calculated by dividing the photocurrent noise by R, the detector's responsivity (see figures 1 and 2 on page 6).

For instance, the Model 2031 on the high gain setting has a minimum photocurrent noise of 0.9 pA/$\sqrt{Hz}$ (see Figure 5c). When operating around 900 nm where the responsivity is about 0.6 A/W, the NEP is 1.5 pW/$\sqrt{Hz}$. From 10 kHz to 90 kHz the photocurrent noise rises by about 10 dB to a peak noise of 2.8 pA/$\sqrt{Hz}$, corresponding to a peak NEP of 4.7 pW/$\sqrt{Hz}$.

From DC to 90 kHz the average photocurrent noise for the Model 2031 on the high gain setting is about 2 pA/$\sqrt{Hz}$, corresponding to an average NEP at 900 nm of 3.3 pW/$\sqrt{Hz}$. The integrated noise equivalent power from DC to 90 kHz is then obtained by multiplying the average NEP by $\sqrt{BW}$, the square root of the bandwidth. The expression $BW = 2\pi f_{3\text{-dB}}/4$ for a one-pole low-pass filter is useful for calculating the equivalent noise bandwidth. For the Model 2031 with a 3-dB bandwidth of 90 kHz, the equivalent noise bandwidth is 140 kHz.

This gives an optical noise equivalent power of about 1.2 nW, so the minimum detectable optical signal at 900 nm (with a signal-to-noise ratio of 1) for the Model 2031 on the high gain setting is 1.2 nW.

Calculating Output-Voltage Noise

The output-voltage noise can be calculated from

$$G \cdot R \cdot NEP \cdot \sqrt{BW},$$

where *G* is the transimpedance gain (V/A), *R* is the photodiode responsivity (A/W), *NEP* is the average noise equivalent power, and *BW* is the bandwidth. This gives an output noise voltage for the Model 2031 on the high gain setting of ($2\text{x}10^6$ V/A) · (0.6 A/W) · (3.3 pW/$\sqrt{Hz}$) $\cdot\sqrt{140kHz}$ =1.5 mV_{rms}.

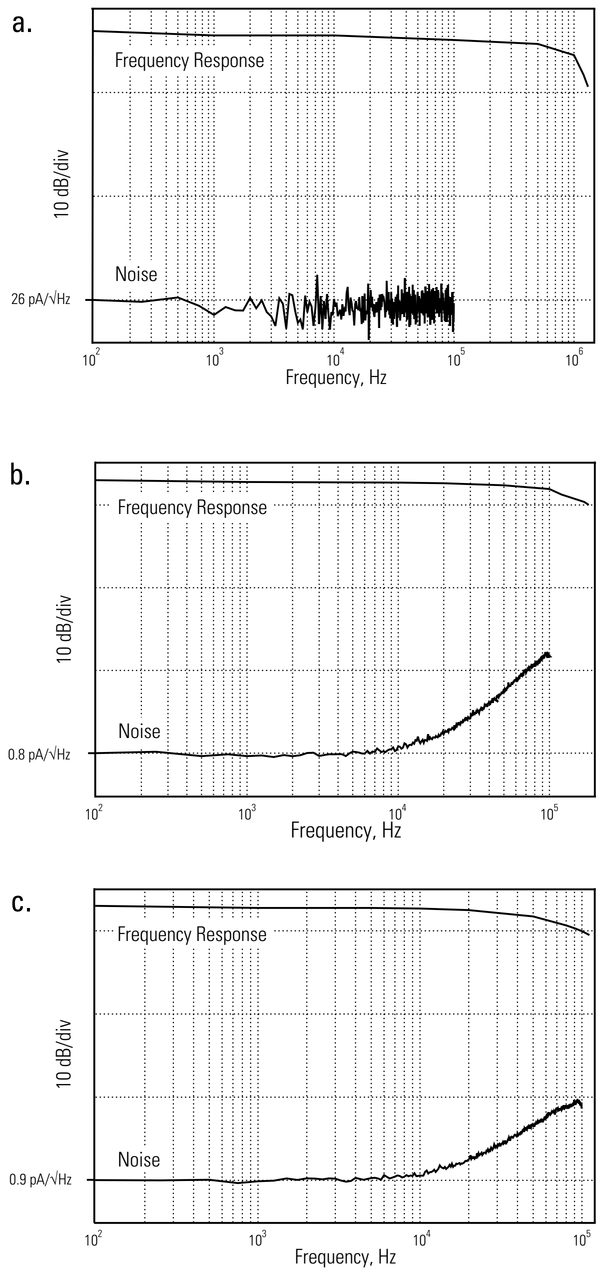
Summary

To summarize, for the Model 2031 on the high gain setting the average NEP is 3.3 pW/$\sqrt{Hz}$, and this yields an output noise voltage of 1.5 mV_{rms}. Viewed another way, for operation at the peak responsivity wavelength of 900 nm and for the High gain setting, you will achieve a signal-to-noise ratio of unity if the input power is 1.2 nW. Note that this assumes operation without any post-photoreceiver filtering and with the full photoreceiver bandwidth of 90 kHz. By using an electronic band-pass filter or an optical chopper and a lock-in amplifier, the receiver can detect significantly weaker optical signals.

Typical Frequency Response and Noise Spectra

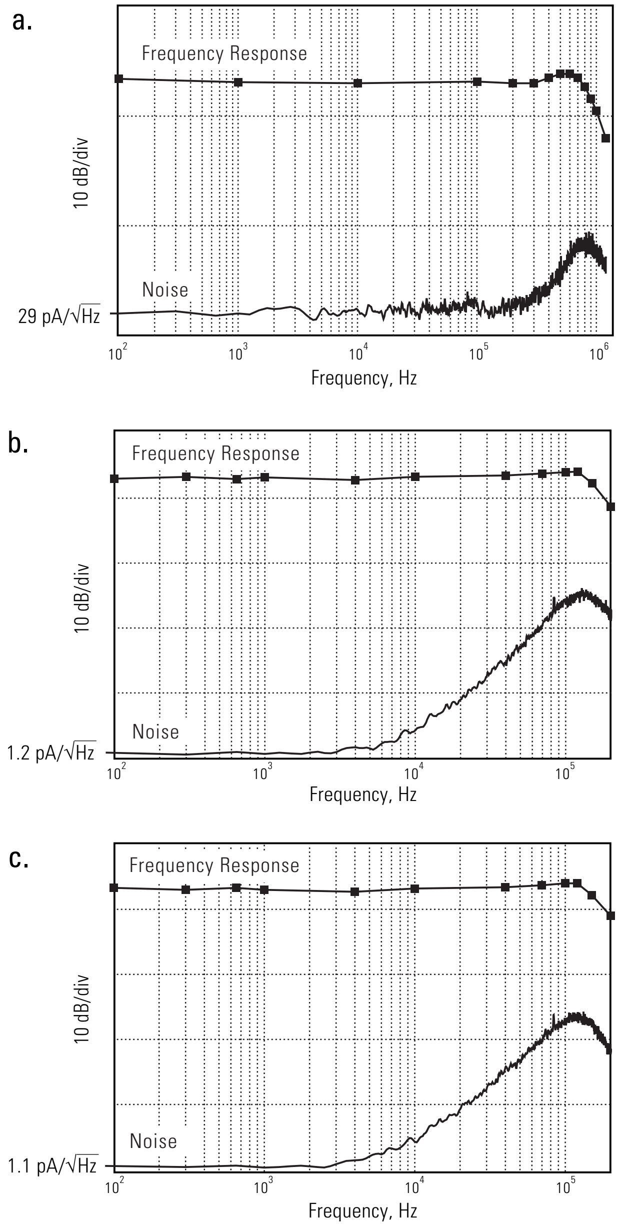
The 3-dB frequency bandwidth is defined as the frequency where the photoreceiver's transimpedance gain has decreased by a factor of $\sqrt{2}$. For the Model 2031 on the low setting the gain is $2\text{x}10^3$ V/A and the bandwidth is 1 MHz. The gain on the medium setting is 10^5 V/A, and the bandwidth is 150 kHz. The gain on the high setting is 2×10^6 V/A, and the bandwidth is 90 kHz. The noise spectrum is plotted in units of photocurrent noise, pA/$\sqrt{Hz}$.

Figure 5: Typical frequency response and noise spectra for the Model 2031 large-area visible photoreceiver with the gain set to (a) Low, (b) Medium, and (c) High



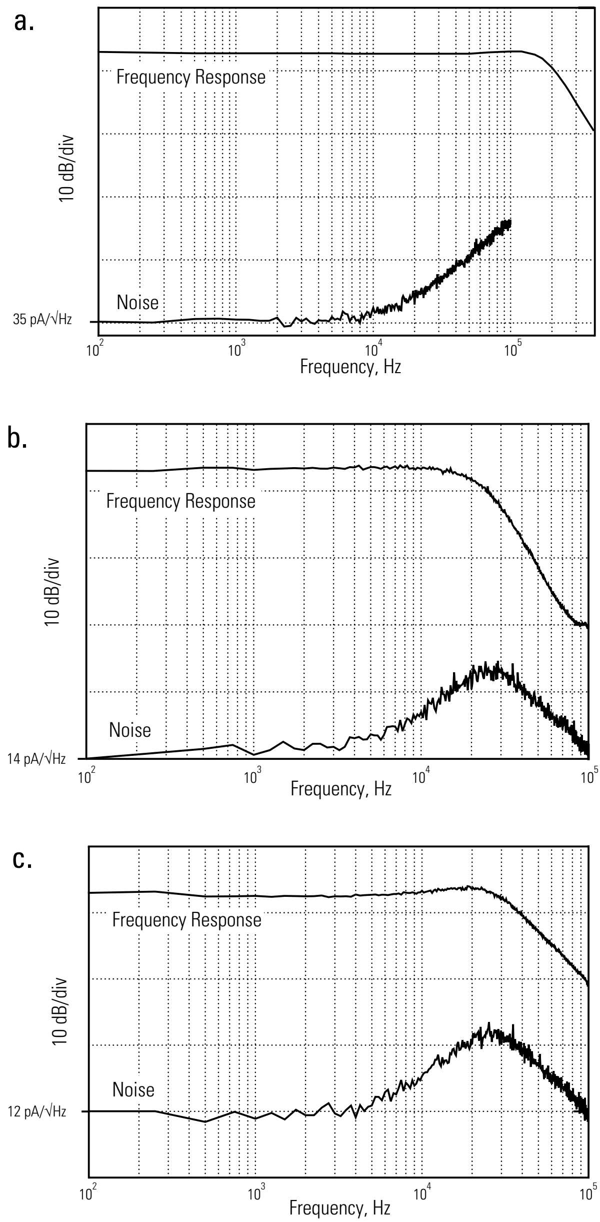
For the Model 2032 the bandwidth is 900 kHz for the low gain setting and 150 kHz for the medium and high gain settings.

Figure 6: Typical frequency response and noise spectra for the Model 2032 UV-enhanced photoreceiver with the gain set to (a) Low, (b) Medium, and (c) High



For the Model 2033 the bandwidth is 200 kHz for the low gain setting, 30 kHz for the medium gain setting, and 30 kHz for the high gain setting.

Figure 7: Typical frequency response and noise spectra for the Model 2033 large-area IR photoreceiver with the gain set to (a) Low, (b) Medium, and (c) High



For the Model 2034 the bandwidth is 700 kHz for the low gain setting, 90 kHz for the medium gain setting, and 80 kHz for the high gain setting.

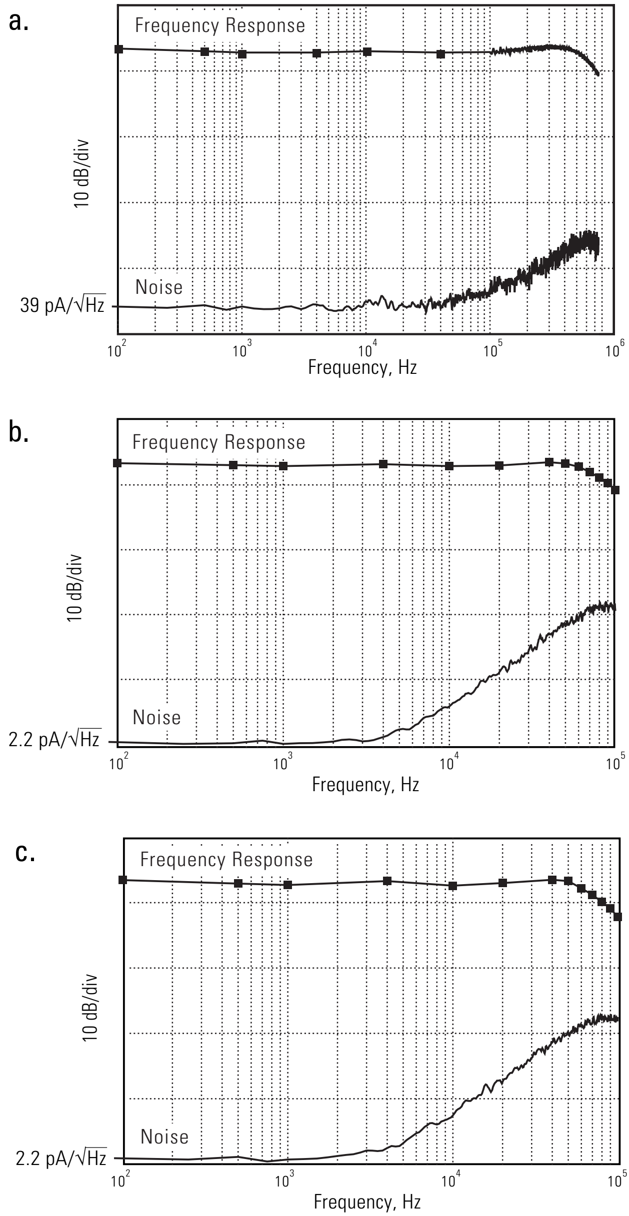


Figure 8: Typical frequency response and noise spectra for the Model 2034 extended-wavelength InGaAs photoreceiver with the gain set to (a) Low, (b) Medium, and (c) High

Using Filters and Optical Fiber

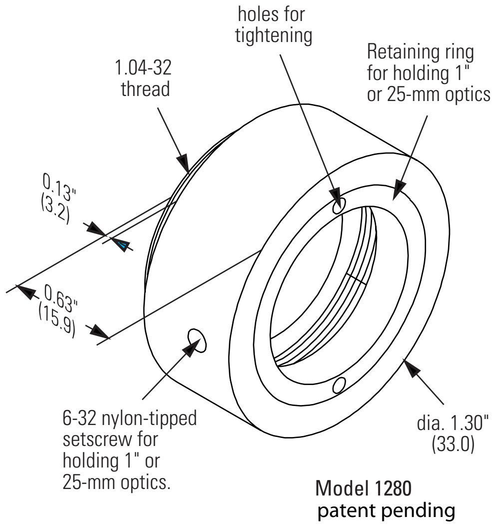
New Focus offers accessories to attach a 1"-diameter filter or an optical fiber to the Model 203X large-area photoreceiver. These accessories are sold separately, and they are not supplied with the photoreceiver. Both accessories attach to the photoreceiver using the 1.04-32 threads located in the casing around the photodetector. Note that the accessories are also compatible with two other New Focus products, the Model 215X femtowatt photoreceiver and the Model 162X nanosecond photodetector.

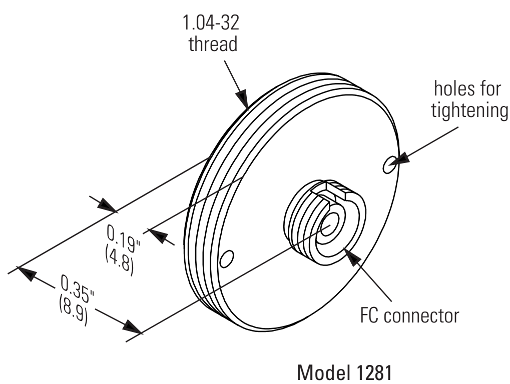
The Model 1280 1" filter holder allows you to mount a 1"-diameter optic in front of the photodetector. For instance, you can mount a colored glass filter to remove unwanted wavelengths or mount a neutral-density filter to attenuate the optical power incident on the photodetector. The Model 1280 has a plastic ring for mounting a filter that is up to about 0.25" (6.4-mm) thick. A thicker optic can be held in place using the 6-32 nylon-tipped set screw. Use a 1/16" or 1.5-mm Allen key or ball-driver to adjust the set screw.

The Model 1281 FC fiber adapter allows you to connect an FC-connectorized fiber to the front of the photodetector.

See Figure 9 on the next page for drawings of these two accessories.

Figure 9: Model 1280 filter holder and Model 1281 FC-fiber adapter

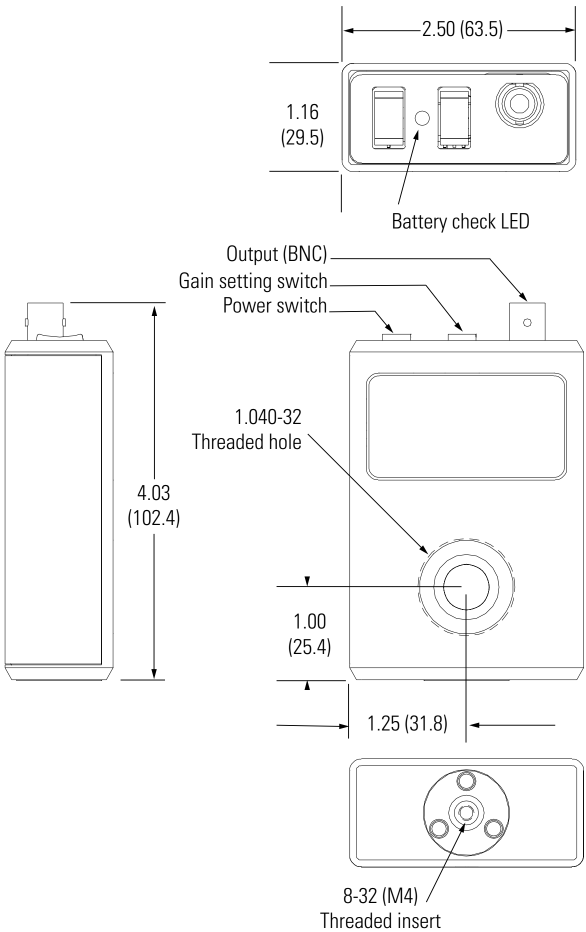




Characteristics

Physical Specifications

Figure 10: Mechanical drawing of the Model 203X casing



Model 2031 Specifications

	Model 2031		
Wavelength Range	400-1070 nm		
Detector Material/Type	Silicon/PIN		
Detector Diameter	8 mm		
Typical Max. Responsivity	0.6 A/W (at 900 nm)		
Maximum Power Density	10 mW/mm^2		
Maximum Optical Power	10 mW		
Gain Settings	Low	Med.	High
Transimpedance Gain (V/A)	$2x10^3$	10^5	$2x10^6$
3-dB Bandwidth	1 MHz	150 kHz	90 kHz
Max. Conversion Gain (V/W)	$1.2x10^3$	$0.6x10^5$	$1.2x10^6$
cw Saturation Pwr (at 900 nm)	4 mW	83 µW	4 µW
Typical Min. NEP (pW/$\sqrt{Hz}$)	43	1.3	1.5
Output Impedance	100 Ω		
Electrical Output Connector	BNC		
Power Requirements	One 9-volt alkaline battery		
Battery Lifetime (approx.)	500 hours		

Model 2032 Specifications

	Model 2032		
Wavelength Range	190–1100 nm		
Detector Material/Type	UV-enhanced silicon/PIN		
Detector Diameter	5.8 mm		
Typical Max. Responsivity	0.5 A/W (at 960 nm)		
Maximum Power Density	10 mW/mm^2		
Maximum Optical Power	10 mW		
Gain Settings	Low	Med.	High
Transimpedance Gain (V/A)	$2x10^3$	10^5	$2x10^6$
3-dB Bandwidth	900 kHz	150 kHz	150 kHz
Max. Conversion Gain (V/W)	$1x10^3$	$0.5x10^5$	$1x10^6$
cw Saturation Pwr (at 960 nm)	5 mW	100 µW	5 µW
Typical Min. NEP ($pW/\sqrt{Hz}$)	58	2.4	2.2
Output Impedance	100 Ω		
Electrical Output Connector	BNC		
Power Requirements	One 9-volt alkaline battery		
Battery Lifetime (approx.)	500 hours		

Model 2033 Specifications

	Model 2033		
Wavelength Range	800–1750 nm		
Detector Material/Type	Ge/PN		
Detector Diameter	5 mm		
Typical Max. Responsivity	0.8 A/W (at 1500 nm)		
Maximum Power Density	6 mW/mm^2		
Maximum Optical Power	10 mW		
Gain Settings	Low	Med.	High
Transimpedance Gain (V/A)	$2x10^3$	10^5	$2x10^6$
3-dB Bandwidth	200 kHz	30 kHz	30 kHz
Max. Conversion Gain (V/W)	$1.6x10^3$	$0.8x10^5$	$1.6x10^6$
cw Saturation Pwr (at 1500 nm)	3 mW	63 μW	3 μW
Typical Min. NEP (pW/$\sqrt{Hz}$)	44	18	15
Output Impedance	100 Ω		
Electrical Output Connector	BNC		
Power Requirements	One 9-volt alkaline battery		
Battery Lifetime (approx.)	500 hours		

Model 2034 Specifications

	Model 2034		
Wavelength Range	800–2200 nm		
Detector Material/Type	extended-wavelength InGaAs/ PIN		
Detector Diameter	1 mm		
Typical Max. Responsivity	1.1 A/W (at 1950 nm)		
Maximum Power Density	5 mW/mm^2		
Maximum Optical Power	5 mW		
Gain Settings	Low	Med.	High
Transimpedance Gain (V/A)	$2x10^3$	10^5	$2x10^6$
3-dB Bandwidth	700 kHz	90 kHz	80 kHz
Max. Conversion Gain (V/W)	$2.2x10^3$	$1.1x10^5$	$2.2x10^6$
cw Saturation Pwr (at 1950 nm)	2.3 mW	45 μW	2.3 μW
Typical Min. NEP (pW/$\sqrt{Hz}$)	35	2	2
Output Impedance	100 Ω		
Electrical Output Connector	BNC		
Power Requirements	One 9-volt alkaline battery		
Battery Lifetime (approx.)	500 hours		

Customer Service

Technical Support

Information and advice about the operation of any New Focus product is available from our applications engineers. For quickest response, ask for "Technical Support" and know the model and serial numbers for your product.

Hours: 8:00–5:00 PST, Monday through Friday (excluding holidays).

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(from the USA & Canada only)
Phone: (408) 284-6808

Support is also available by fax and email:

Fax: (408) 980-8883
Email: techsupport@newfocus.com

We typically respond to faxes and email within one business day.

Service

In the event that your photoreceiver malfunctions or becomes damaged, please contact New Focus for a return authorization number and instructions on shipping the unit back for evaluation and repair.