Operation Manual

Thorlabs Instrumentation

PDB100 Series

Balanced Amplified Photodetectors

PDB110, PDB120, PDB130, PDB140, PDB145, PDB150

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We aim to develop and produce the best solution for your application in the field of optical measurement technique. To help us to come up to your expectations and develop our products permanently we need your ideas and suggestions. Therefore, please let us know about possible criticism or ideas. We and our international partners are looking forward to hear from you.

Thorlabs GmbH

This part of the instruction manual contains every specific information on how to handle and use the PDB100 series Balanced Amplified Photodetectors. A general description is followed by explanations of how to operate the unit.

☝Attention☝

This manual contains “WARNINGS” and “ATTENTION” label in this form, to indicate danger for persons or possible damage of equipment.

Please read these advises carefully!

NOTE

This manual also contains “NOTES” and “HINTS” written in this form.

1 Overview

Thorlabs PDB100 series Balanced Amplified Photodetectors consist of two well-matched photodiodes and an ultra-low noise, high-speed transimpedance amplifier that generates an output voltage proportional to the difference between the photocurrents in the two photodiodes, i.e. the two optical input signals.

The “Getting Started Quickly” section (see ch. 2) gives an overview of how to set up the PDB100 series Balanced Amplified Photodetectors. Subsequent sections contain detailed information about principle of operation, operating suggestions and technical specifications.

The following models of PDB100 series are available:

PDB110 – 100 MHz, fixed gain Balanced Amplified Photodetectors
PDB120 – 75 MHz, OCT-proved fixed gain Balanced Amplified Photodetectors
PDB130 – 350 MHz, fixed gain Balanced Amplified Photodetectors
PDB140 – 15 MHz, OCT-proved fixed gain Balanced Amplified Photodetectors with active aliasing filter
PDB145 – 15 MHz, OCT-proved fixed gain Balanced Amplified Photodetectors with active aliasing filter
PDB150 – 150 MHz, gain switchable Balanced Amplified Photodetectors

According to Thorlabs general detector part numbering system, appendix “A” indicates Si photodiodes while appendix “C” indicates InGaAs photodiodes.

AC-coupled versions of each model can be ordered on request.

Open detector versions (detector cover glass removed) of each model can be ordered on request.

Please refer to www.thorlabs.com for new models.

1.1 Safety

☝ Attention ☝

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly.

Before connecting the power supply to the mains make sure that the line voltage range marked on the power supply agrees with your local supply.

The unit must not be operated in explosion endangered environments!

Only with written consent from Thorlabs GmbH may changes to single components be carried out or components not supplied by Thorlabs GmbH be used.

This precision device is only dispatchable if duly packed into the complete original packaging including the plastic form parts. If necessary, ask for a replacement package.

☝ Attention ☝

Mobile telephones, handy phones or other radio transmitters are not to be used within the range of three meters of this unit since the electromagnetic field intensity may then exceed the maximum allowed disturbance values according to EN 50 082-1.

2 Getting Started Quickly

This section is intended to provide information how to set up quickly the Balanced Amplified Photodetectors. More details and advanced features are described in further sections.

2.1 Parts List – Accessories

The Balanced Amplified Photodetectors system consists of the following items:

- **PDB1xx** Balanced Amplified Photodetectors
- Adapter Plate with four M2x8 screws and a hex key 1.5, for post-mounting the unit on a optical table
- Power supply (±12V, 0.2A), 110V or 230V line voltage
- Operation manual

NOTE

Please check prior to operation, if the indicated line voltage range on the power supply matches with your local mains voltage!

NOTE

If you want use your own power supply, you can ask Thorlabs for an appropriate power connector cable.

2.2 Setup

- Carefully unpack the unit and accessories. If any damage is noticed, do not use the unit. Call Thorlabs and have us replace the defective unit.
- If necessary, mount the unit on your optical table. Therefor, mount the adapter plate on bottom or side wall using the four M2x8 screws first. The adapter plate has two mounting holes, M4 and #8-32. The M4 thread is marked.
- Plug the power connector cable into the DC INPUT.
- Plug the power supply into a 50-60 Hz, 100-120 VAC outlet (220V-240 VAC for EC version). The green LED on the PDB1xx indicates correct power supply.
- Connect to RF OUTPUT coaxial cable.
- If necessary, connect monitor outputs (MONITOR+, MONITOR-) to measure the optical input power for each channel individually. The monitor outputs are designed to drive loads with high impedance only.

2.3 Operating Instructions

- Connect the optical source(s) to the optical input(s). The FC adapter will accommodate multi-mode as well as single-mode fiber.
- For free-space beam applications FC-adapters can be removed in order to have direct access to the photodetectors (not for PDB130C - see chapter 3.2.2 for details). MONITOR outputs can be used for convenient alignment of input free-space beams. The maximum output voltage swing of the MONITOR outputs is 10 V. Saturation of the MONITOR outputs will occur at optical input power greater than 1 mW for models PDB110, PDB120, PDB130 and PDB150 and at greater than 100 µW for models PDB140 and PDB145.
- The maximum RF OUTPUT voltage swing of the fixed gain versions (PDB110, PDB120, PDB130, PDB140, PDB145) is ±3.6 V for high impedance loads (±1.8 V into 50 Ω loads). The output signal must not exceed this maximum output voltage to avoid saturation. External neutral density filters or attenuators are recommended to reduce the input light level in critical cases. One model - PDB150 - offers switchable gain - for details see chapter 3.1.6.
- For balanced operation illuminate both photodetectors simultaneously and use either the RF OUTPUT or the MONITOR outputs to fine-tune the optical power balance by observing voltage on a digital voltmeter or other low-frequency measurement device.

- Do not exceed a maximum power density of 4 W/cm^2 for maximum linearity performance when measuring focused beams, fiber outputs, or small diameter beams.

NOTE

To prevent saturation of the amplifier keep the difference between the optical input powers less than the saturation power listed in specification.

☝ Attention ☝

Refer to the specification and pay attention to the optical damage threshold!

Exceeding these values will permanently destroy the detectors!

3 Detailed Description

3.1 Technical Data

3.1.1 PDB110x

	PDB110A	PDB110C
Detector Material/Type	Si / PIN	InGaAs / PIN
Wavelength Range	320 nm-1000 nm	800 nm-1700 nm
Typical Max. Responsivity	0.53 A/W	1.0 A/W
Detector Diameter	0.8 mm	0.3 mm
Bandwidth (3dB)	DC-100 MHz	
Common Mode Rejection Ratio	25 dB guaranteed > 35 dB typical	
Transimpedance Gain	50×10^3 V/A 25×10^3 V/A with 50 Ω termination	
Conversion Gain RF-Output	26.5×10^3 V/W	50×10^3 V/W
Conversion Gain Monitor Outputs	10 V/mW @ 820 nm	10 V/mW @ 1550 nm
CW Saturation Power	130 µW @ 820 nm	70 µW @ 1550 nm
Optical Inputs	FC (Removable)	
Max. Input Power (photodiode damage threshold))	20 mW	
Electrical outputs	SMA	
RF-Output Impedance	50Ω	
Minimum NEP (DC-10 MHz)	7 pW/√Hz	3.8 pW/√Hz
Size	85x80x30mm	
Power Supply	±12 V, 200 mA	

(All accuracy data are given at 23 ± 5°C and 45 ±15% humidity)

3.1.2 PDB120x

	PDB120A	PDB120C
Detector Material/Type	Si / PIN	InGaAs / PIN
Wavelength Range	320 nm - 1000 nm	800 nm - 1700 nm
Typical Max. Responsivity	0.53 A/W	1.0 A/W
Detector Diameter	0.8 mm	0.3 mm
Bandwidth (3dB)	DC - 75 MHz	
Common Mode Rejection Ratio	> 35 dB	
Transimpedance Gain	180 x 10^3 V/A 90 x 10^3 V/A with 50 Ω termination	
Conversion Gain RF-Output	95 x 10^3 V/W	180 x 10^3 V/W
Conversion Gain Monitor Outputs	10 V/mW @ 820 nm	10 V/mW @ 1550 nm
CW Saturation Power	38 µW @ 820 nm	20 µW @ 1550 nm
Optical Inputs	FC (Removable)	
Max. Input Power (photodiode damage threshold))	20 mW	
Electrical outputs	SMA	
RF-Output Impedance	50Ω	
NEP (DC-10MHz)	6.5 pW/√Hz	3.3 pW/√Hz
DC-offset RF Output	< ± 2 mV	
Size	85x80x30mm	
Power Supply	±12 V, 200 mA	

(All accuracy data are given at 23 ± 5°C and 45 ±15% humidity)

3.1.3 PDB130x

	PDB130A	PDB130C
Detector Material/Type	Si / PIN	InGaAs / PIN
Wavelength Range	320 nm-1000 nm	800 nm-1700 nm
Typical Max. Responsivity	0.5 A/W	1.0 A/W
Detector Diameter	0.4 mm	0.15 mm
Bandwidth (3dB)	DC-350 MHz	
Common Mode Rejection Ratio	20 dB guaranteed > 25 dB typical	
Transimpedance Gain	10×10^3 V/A 5×10^3 V/A with 50 Ω termination	
Conversion Gain RF-Output	5×10^3 V/W	10×10^3 V/W
Conversion Gain Monitor Outputs	10 V/mW @ 820 nm	10 V/mW @ 1550 nm
CW Saturation Power	700 μW @ 820 nm	400 μW @ 1550 nm
Optical Inputs	FC (Removable)	FC (**NOT** Removable)
Max. Input Power (photodiode damage threshold))	20 mW	
Electrical outputs	SMA	
RF-Output Impedance	50Ω	
Minimum NEP (DC-100 MHz)	14.7 pW/√Hz	7.4 pW/√Hz
Size	85x80x30mm	
Power Supply	±12 V, 200 mA	

(All accuracy data are given at 23 ± 5°C and 45 ±15% humidity)

3.1.4 PDB104x

	PDB140A	PDB140C
Detector Material/Type	Si / PIN	InGaAs / PIN
Wavelength Range	320 nm - 1000 nm	800 nm - 1700 nm
Typical Max. Responsivity	0.53 A/W	1.0 A/W
Detector Diameter	0.8 mm	0.3 mm
Bandwidth (3dB)	DC - 15 MHz	
Common Mode Rejection Ratio	> 35 dB	
Transimpedance Gain*	560 x 10^3 V/A	
Conversion Gain RF-Output	297 x 10^3 V/W	560 x 10^3 V/W
Conversion Gain Monitor Outputs	100 V/mW @ 820 nm	100 V/mW @ 1550 nm
CW Saturation Power	12 µW @ 820 nm	6.5 µW @ 1550 nm
Optical Inputs	FC (Removable)	
Max. Input Power (photodiode damage threshold))	20 mW	
Electrical outputs	SMA	
RF-Output Impedance	50Ω	
NEP (DC-10MHz)	5.7 pW/√Hz	3.2 pW/√Hz
DC-offset RF Output	< ± 2 mV	
Size	85x80x30mm	
Power Supply	±12 V, 200 mA	

*** Transimpedance gain is reduced by factor 2 into 50 Ohm load.**

(All accuracy data are given at 23 ± 5°C and 45 ±15% humidity)

3.1.5 PDB145x

	PDB145A	PDB145C
Detector Material/Type	Si / PIN	InGaAs / PIN
Wavelength Range	320 nm - 1000 nm	800 nm - 1700 nm
Typical Max. Responsivity	0.53 A/W	1.0 A/W
Detector Diameter	0.8 mm	0.3 mm
Bandwidth (3dB)	DC - 15 MHz	
Common Mode Rejection Ratio	> 35 dB	
Transimpedance Gain*	51 x 10^3 V/A	
Conversion Gain RF-Output	27 x 10^3 V/W	51 x 10^3 V/W
Conversion Gain Monitor Outputs	100 V/mW @ 820 nm	100 V/mW @ 1550 nm
CW Saturation Power	130 µW @ 820 nm	70 µW @ 1550 nm
Optical Inputs	FC (Removable)	
Max. Input Power (photodiode damage threshold))	20 mW	
Electrical outputs	SMA	
RF-Output Impedance	50Ω	
NEP (DC-10MHz)	5.7 pW/√Hz	3.2 pW/√Hz
DC-offset RF Output	< ± 2 mV	
Size	85x80x30mm	
Power Supply	±12 V, 200 mA	

*** Transimpedance gain is reduced by factor 2 into 50 Ohm load.**

(All accuracy data are given at 23 ± 5°C and 45 ±15% humidity)

3.1.6 PDB150x

	PDB150A	PDB150C
Detector Material/Type	Si / PIN	InGaAs / PIN
Wavelength Range	320 nm-1000 nm	800 nm-1700 nm
Typical Max. Responsivity	0.53 A/W	1.0 A/W
Detector Diameter	0.8 mm	0.3 mm
Bandwidth (3dB)	150 / 50 / 5 / 0.3 / 0.1 MHz	
Common Mode Rejection Ratio	25 dB guaranteed > 30 dB typical	
Transimpedance Gain*	10^3 / 10^4 / 10^5 / 10^6 / 10^7 V/A	
Conversion Gain RF-Output	0.53x10^3 / 0.53x 10^4 0.53x10^5 / 0.53x 10^6 0.53x 10^7 V/W	10^3 / 10^4 / 10^5 / 10^6 / 10^7 V/W
Conversion Gain Monitor Outputs	10 V/mW @ 820 nm	10 V/mW @ 1550 nm
CW Saturation Power	10 mW @ 820 nm	5 mW @ 1550 nm
Optical Inputs	FC (Removable)	
Max. Input Power (photodiode damage threshold))	20 mW	
Electrical outputs	SMA	
RF-Output Impedance	50Ω	
Minimum NEP (DC-10 MHz)	0.6 pW/√Hz	0.3 pW/√Hz
Size	85x80x30mm	
Power Supply	±12 V, 200 mA	

*** Transimpedance gain is reduced by factor 2 into 50 Ohm load.**

(All accuracy data are given at 23 ± 5°C and 45 ±15% humidity)

3.2 Physical Overview

3.2.1 Post mounting the PDB100 series

The PDB100 series is housed in a rugged aluminum shielded enclosure of 85x80x30 mm dimensions. For post mounting an adapter can be attached to the bottom or side surface using four M2x8 screws (see Figure 1). This adapter supports #8-32 as well as M4 post mounts. The M4 tread is marked.

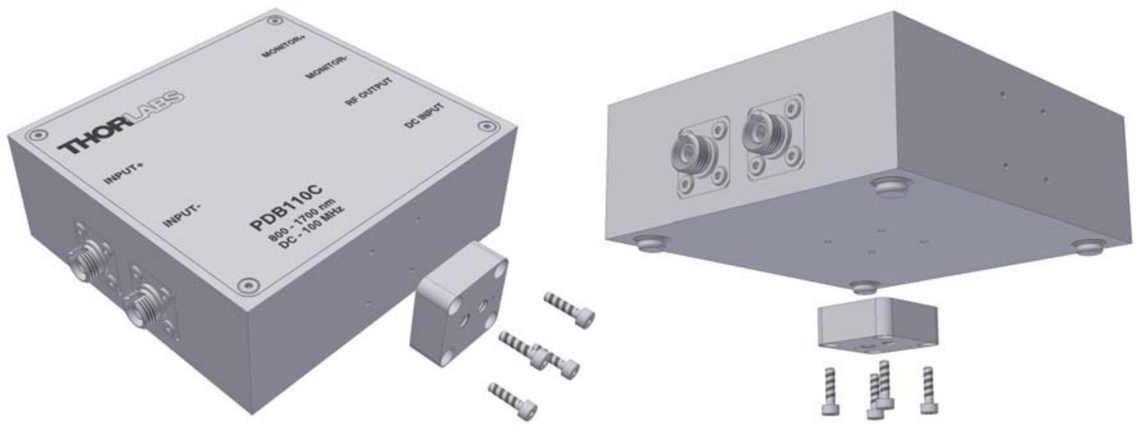


Figure 1 Possible positions of the adapter for post mounting

3.2.2 Optical Inputs

For all models except PDB130C the fiber inputs are coupled to the photodiodes using two removable FC adapters. These FC receptacles accommodate either single-mode or multi-mode fiber with FC/PC or FC/APC connectors as well. Model PDB130C uses also FC adapters, but not removable.

For all PDB1xx**C** models (except PDB130C) the FC adapters are aligned for FC/PC connectors using Corning SMF28™ single mode fiber. When using FC/APC connectors, minimal alignment errors may occur due to small detector size, which will result in a reduced output signal. In such case, FC receptacle can be rotated from its original position in steps of 90° to check for an improved alignment. For this process use an optical input power below the saturation power while observing RF OUTPUT voltage on a digital voltmeter or other low-frequency measurement device. If you have an AC-coupled version, use either MONITOR output (CW signal) or RF OUTPUT (modulated optical signal) with connected oscilloscope for measurement.
In general, multi-mode fiber at the input can be used, but in this case the light beam spot diameter exceeds detector's active area, which results in a reduced output signal as well.

For free-space beam applications it is recommended to remove FC adapter (receptacle) to have direct access to the photodiodes (see Figure 2).

*Figure 2: Removable FC adapters (**not** PDB130C!)*

NOTE

FC adapters (receptacles) are **not** removable from PDB130C enclosure!

Optical damage threshold is 20 mW. Exceeding this value will permanently damage the photodiodes!

Do not exceed a maximum power density of 4 W/cm^2 for maximum linearity performance when measuring focused or small diameter beams. Always try to illuminate the whole detector active area to prevent nonlinearities. Equal power densities on both detectors are important for maximum common mode noise suppression (CMRR).

The PDB100 series can be used in balanced mode (both inputs are illuminated) as well as in single detector mode. In single detector mode, the RF OUTPUT swing depends on which INPUT is used, it is positive for INPUT+ and negative for INPUT-.

In single detector mode the optical input power should be below the CW saturation power listed in specification to avoid saturation of the RF OUTPUT amplifier.

In balanced mode the difference between the optical input powers should be less than the CW Saturation Power. If necessary, use external neutral density filters or attenuators to reduce the input light level.

3.2.3 Electrical Outputs

The PDB100 series has three SMA output connectors carrying INPUT**+** / INPUT**-** monitoring signals (MONITOR**+** / MONITOR**-**) and the balanced output signal (RF OUTPUT).

RF OUTPUT delivers an output voltage proportional to the difference between the photocurrents in the two photodiodes, i.e. the two optical input signals, which is amplified by an ultra-low noise, high-speed transimpedance amplifier. The maximum output voltage swing of the RF OUTPUT for all fixed gain models (PDB110, PDB120, PDB130, PDB140, PDB145) is ±3.6 V for high impedance loads (±1.8 V into 50 Ω). The output signal should not exceed the maximum output voltage to avoid saturation. Therefore the optical input power (or the difference between the optical input powers) should not exceed CW Saturation Power listed in specifications. For details about the gain switchable PDB150 see chapter 3.1.6.

The signal monitor outputs (MONITOR+ and MONITOR-) allow observation of the input power levels and can be used as independent power meters for each channel. These outputs are low frequency outputs and cannot be used to measure an RF modulation on the signal. The conversion gain of the monitor output is 10 V/mW for model PDB110, PDB120, PDB130 and PDB150, calibrated at a wavelength listed in the specification. For PDB140 and PDB145, the conversion gain of the monitor output is 100 V/mW at the wavelength listed in the specification. The maximum output voltage swing of the MONITOR output is +10 V. Saturation of MONITOR outputs will occur at optical input power level greater than 1 mW (100µW for model PDB140, PDB145), depending on the detectors' wavelength response. The monitor outputs are designed to drive high-impedance loads only!

Monitor outputs can be used to roughly adjust equal input power levels on each detector for balanced operation. While the DC-component of the RF OUTPUT in balanced mode is zero, the monitor outputs provide capability to independently observe the individual optical input power. MONITOR outputs of the unit are also convenient to use for free-space beam alignment.

NOTE

The monitor outputs are designed to drive high impedance loads only!

3.3 General Principle of Operation

Thorlabs PDB100 series Balanced Amplified Photodetectors consists of two well-matched photodiodes and an ultra-low noise, high-speed transimpedance amplifier that generates an output voltage (RF OUTPUT) proportional to the difference between the photocurrents of the two photodiodes, i.e. the two optical input signals.
Additionally, the unit has two monitor outputs (MONITOR+ and MONITOR-) to observe the optical input power levels on each photodiode separately. These outputs are low frequency outputs and cannot be used to measure any RF modulation of the signal.
The PDB100 series is powered by external power supply (±12 V, 200 mA - included) via a PICO M8 power connector.
Figure 3 shows a functional block diagram of the PDB100 series balanced amplified photodetectors.

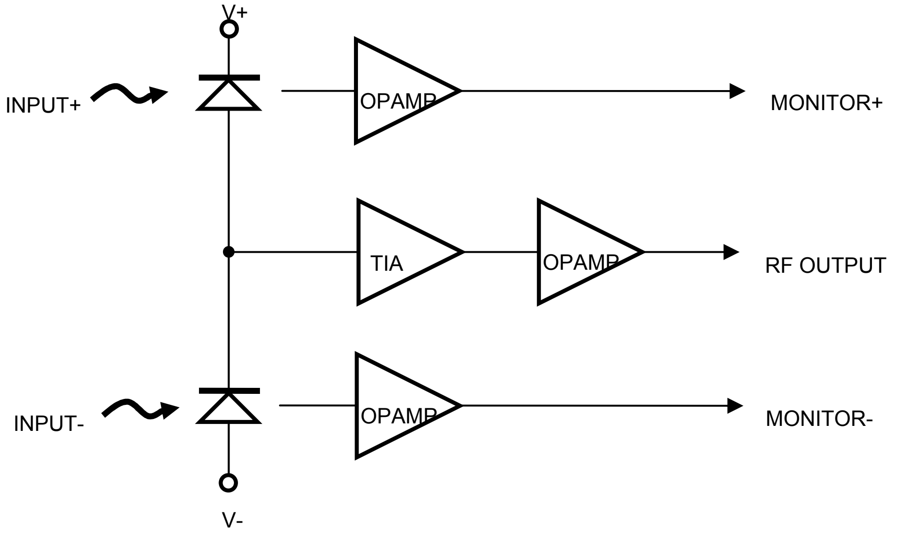


Figure 3: PDB100 series Functional block diagram

3.4 Detector Responsivity

All models PDB1xx**A** (except PDB130A) use a well-matched pair of silicon PIN photodiodes with a detector diameter of 0.8 mm, while all models PDB1xx**C** (except PDB130C) uses a well-matched pair of InGaAs PIN photodiodes with a detector diameter of 0.3 mm. Model PDB130A uses a well-matched pair of silicon PIN photodiodes with a detector diameter of 0.4 mm, and PDB130C a well-matched pair of InGaAs PIN photodiodes with a detector diameter of 0.15 mm.
Figure 4 and Figure 5 show typical responsivity curves for each type of the photodiode.

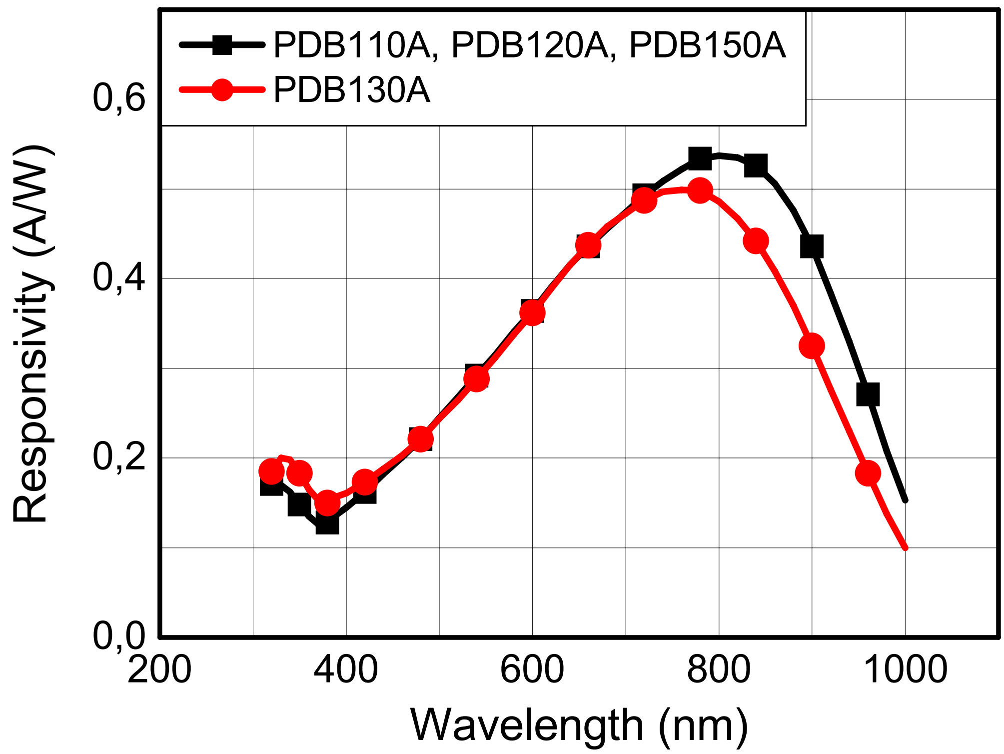


Figure 4: PDB1xxA detector responsivity

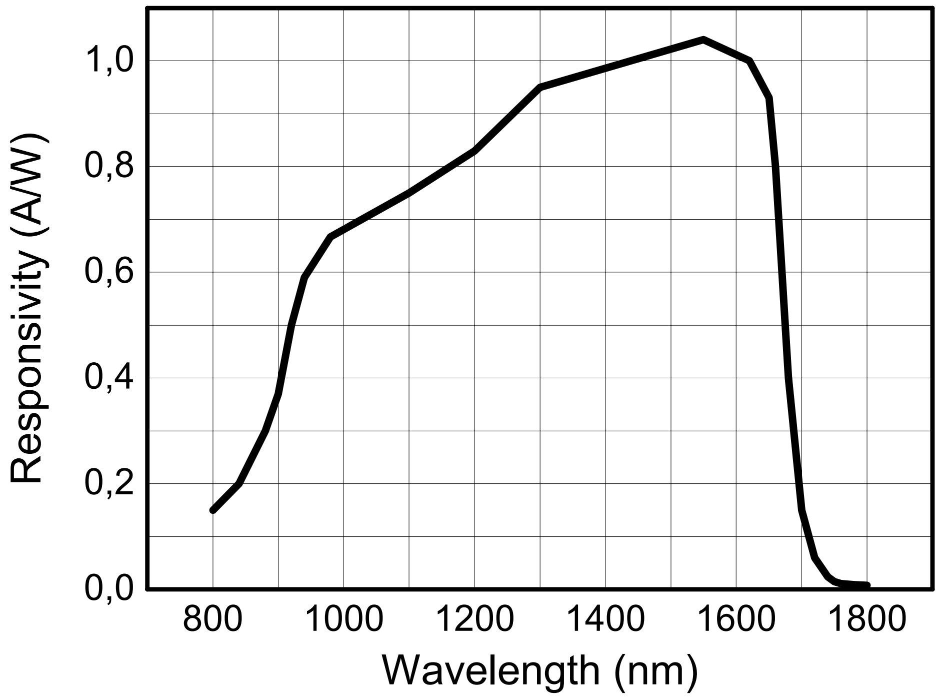


Figure 5: PDB1xxC detector responsivity

For maximum linear performance during measurement of focused beams, fiber outputs, or small diameter beams, do not exceed a maximum power density of 4 W/cm^2.

3.5 Gain, Bandwidth and Noise

The PDB100 series utilizes ultra-low noise, high-speed transimpedance low output impedance amplifiers, generating an output voltage (RF OUTPUT) proportional to the difference between the photocurrents of the two photodiodes, i.e. the two optical input signals. Depending on wavelength responsivity of the detectors, the amplifier will reach saturation when the difference between the two optical input signals is greater than CW Saturation Power listed in specification. For all fixed gain models (PDB110, PDB120, PDB130, PDB140, PDB145), the maximum output voltage swing of the RF OUTPUT is ±3.6 V for high impedance loads and ±1.8 V into 50 Ω loads. Details about gain, bandwidth and noise performance for each model are described in the following sections.

3.5.1 Model PDB110

For PDB110 amplifiers, transimpedance gain is $50x10^3$ V/A for high impedance loads and $25x10^3$ V/A into 50 Ω load. Depending on wavelength responsivity of the detectors, the amplifier will reach saturation if the difference between the two optical input signals is greater than 130 µW for model PDB110A and 70 µW for model PDB110C.

The 3 dB bandwidth of the RF OUTPUT is typically in excess of 100 MHz. Figure 6 and Figure 7 show typical frequency response curves for PDB110A and PDB110C accordingly. For measurement setup see chapter 3.7.

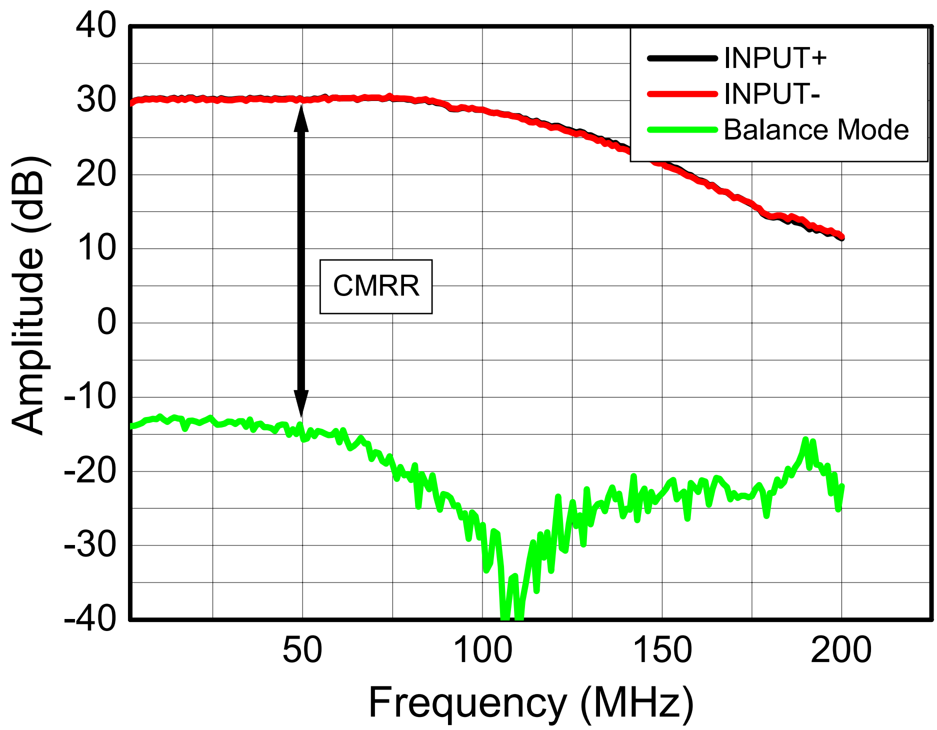


Figure 6: PDB110A frequency response

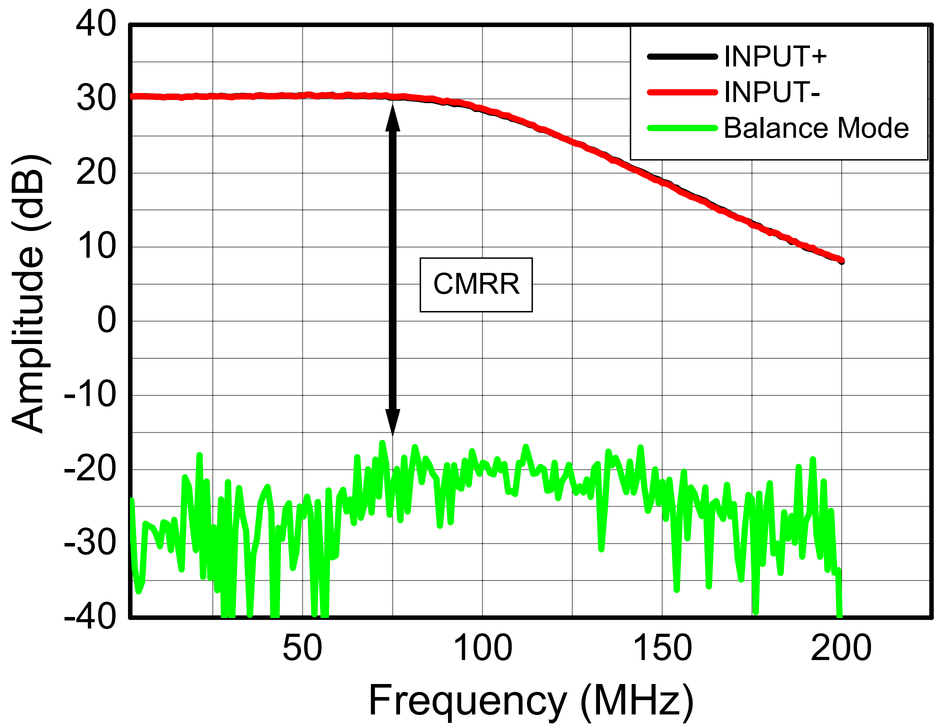


Figure 7: PDB110C Frequency response

Figure 8 and Figure 9 show typical noise spectra of PDB110x (RF OUTPUT) measured using electrical spectrum analyzer (RBW 100 kHz, Video BW 10 kHz). The INPUTs of the PDB110x were blocked. The lower curve is measured with the same setup and PDB110x switched off , i.e., it represents the measurement system's noise floor.

Model PDB110A has a minimum noise equivalent power (NEP) of 7 pW/√Hz, PDB110C - 3.8 pW/√Hz from DC-10 MHz. The difference is caused by different detector responsivities. The integrated noise from DC-100 MHz is 115 nW_{RMS} (PDB110A) and 72 nW_{RMS} for PDB110C. This input optical noise level is the approximate minimum optical signal which can be detected with these models. For PDB110, the overall output voltage noise (V_{RMS}) across a 50 Ohm load is 2,4 mV_{RMS}.

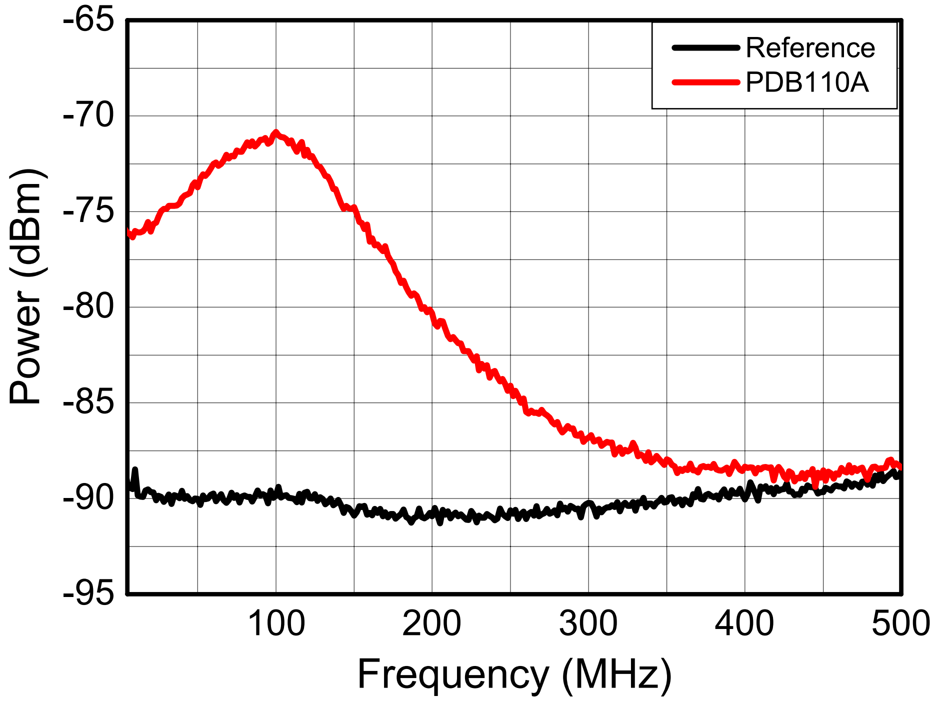


Figure 8: PDB110A spectral noise

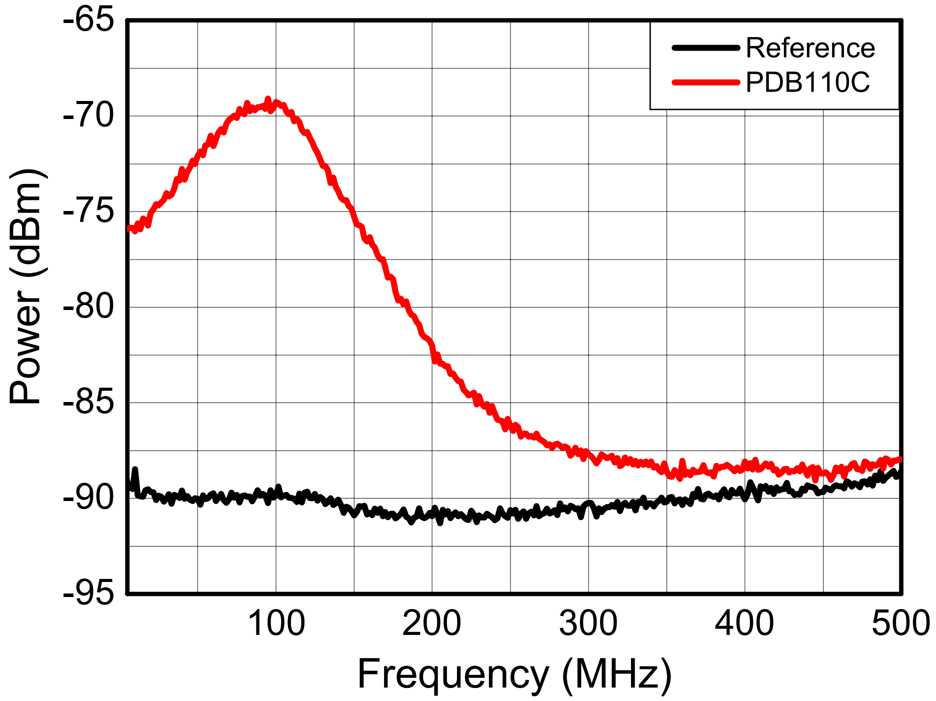


Figure 9: PDB110C spectral noise

3.5.2 Model PDB120

The PDB120 amplifier's transimpedance gain is $180x10^3$ V/A for high impedance loads and $90x10^3$ V/A into 50 Ω load. Depending on wavelength responsivity of the detector, the amplifier will reach saturation if the difference between the two optical input signals is greater than 38 µW for model PDB120A and 20 µW for model PDB120C.

The 3 dB bandwidth of the RF OUTPUT is typically in excess of 75 MHz. Figure 10 and Figure 11 show typical frequency response curves for PDB120A and PDB120C. For measurement setup see chapter 3.7.

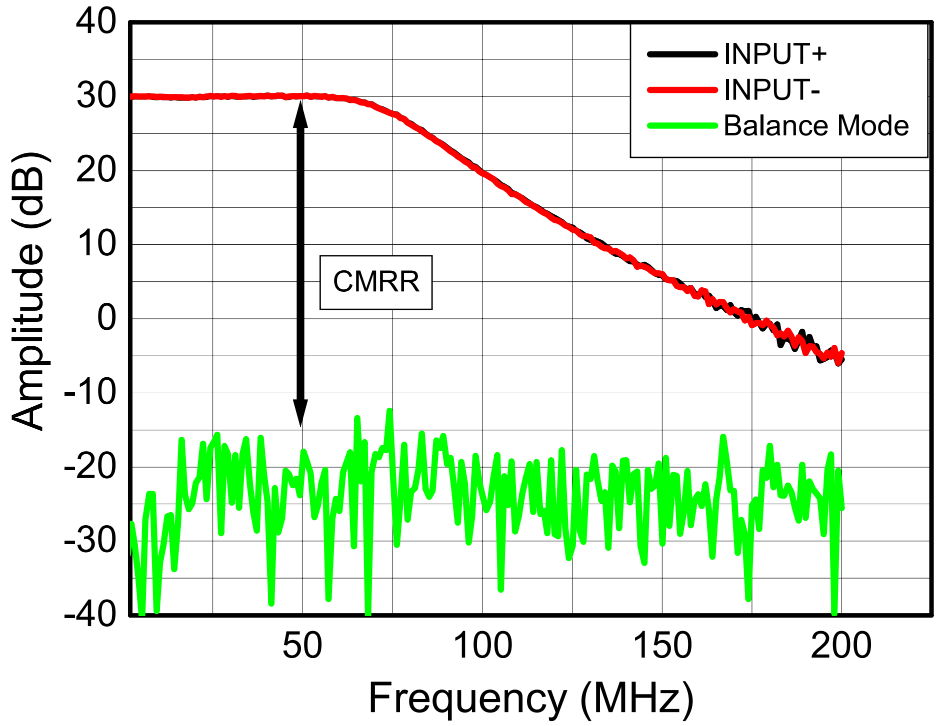


Figure 10: PDB120A Frequency response

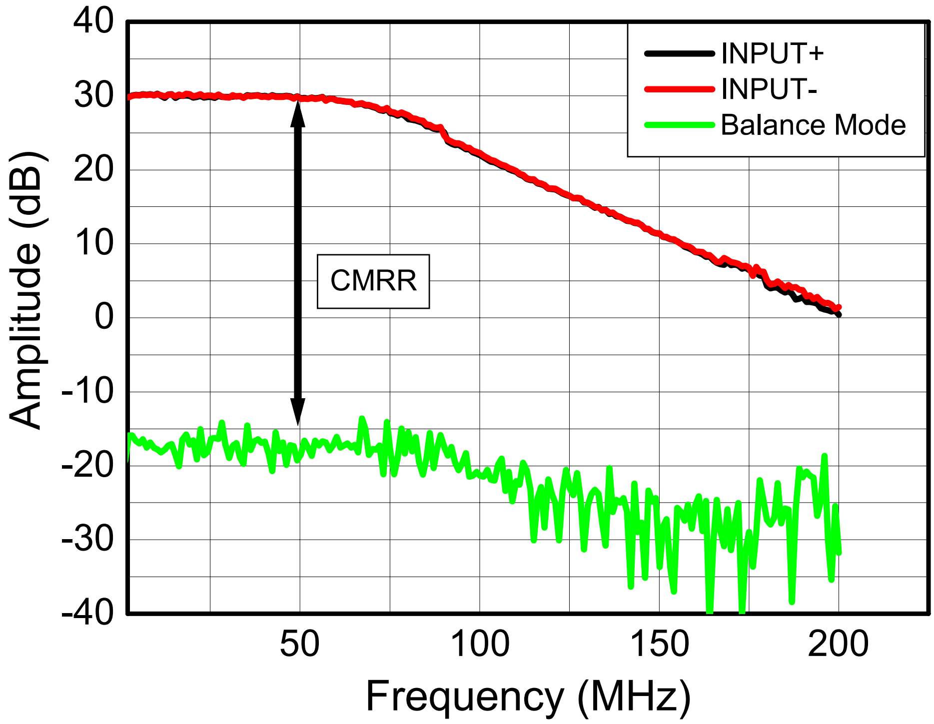


Figure 11: PDB120C Frequency response

Figure 12 and Figure 13 show typical noise spectra of PDB120x (RF OUTPUT) measured using electrical spectrum analyzer (RBW 100 kHz, Video BW 1 kHz). The INPUTs of the PDB120x were blocked. The lower curve is measured with the same setup and PDB120x switched off , i.e., it represents the measurement system's noise floor.

Model PDB120A has a minimum noise equivalent power (NEP) of 6.5 pW/√Hz, PDB120C - 3.3 pW/√Hz from DC-10 MHz. The difference is caused by different detector responsivities. The integrated noise from DC - 75 MHz is 92 nW_{RMS} for model PDB120A and 53 nW_{RMS} for PDB120C. This input optical noise level is the approximate minimum optical signal which can be detected with these models. For PDB120, the overall output voltage noise (V_{RMS}) across a 50 Ohm load is 5,5 mV_{RMS}.

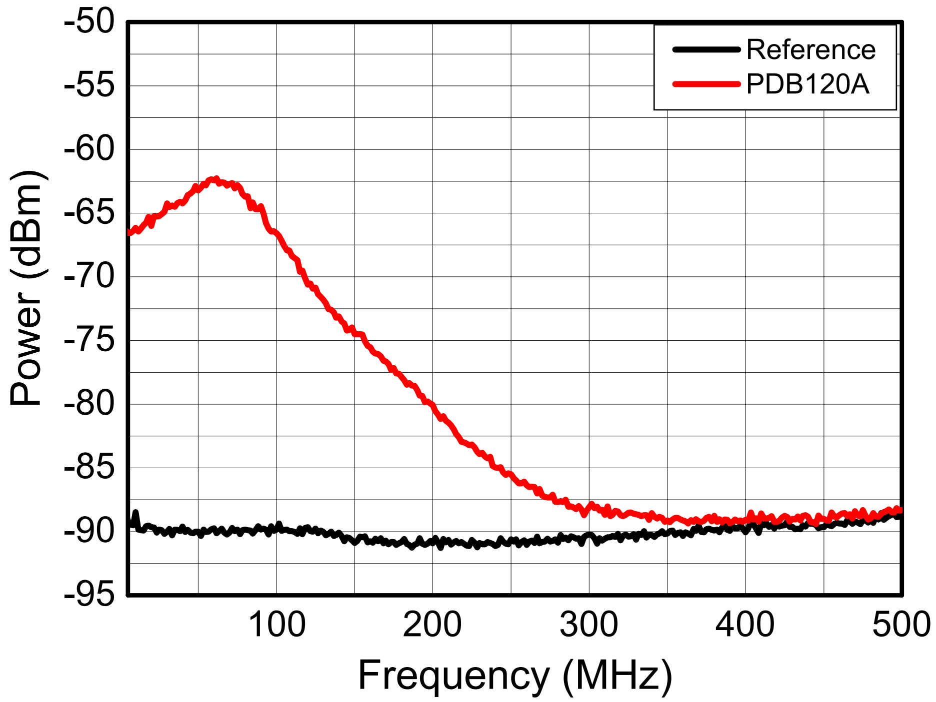


Figure 12: PDB120A spectral noise

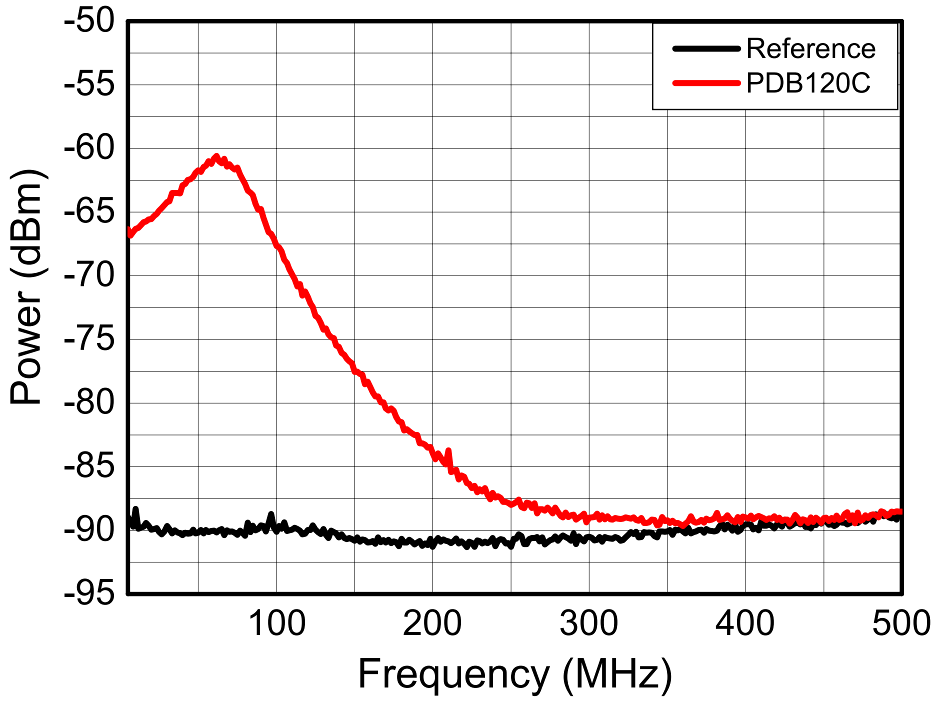


Figure 13: PDB120C spectral noise

3.5.3 Model PDB130

The PDB130 amplifier's transimpedance gain is $10x10^3$ V/A for high impedance loads and $5x10^3$ V/A for 50 Ω loads. Depending on wavelength responsivity of the detectors the amplifier will reach saturation if the difference between the two optical input signals is greater than 700 µW for model PDB130A resp. 400 µW for PDB130C.
The 3 dB bandwidth of the RF OUTPUT is typically in excess of 350 MHz. Figure 14 and Figure 15 show typical frequency response curves for PDB130A and PDB130C. For measurement setup see chapter 3.7.

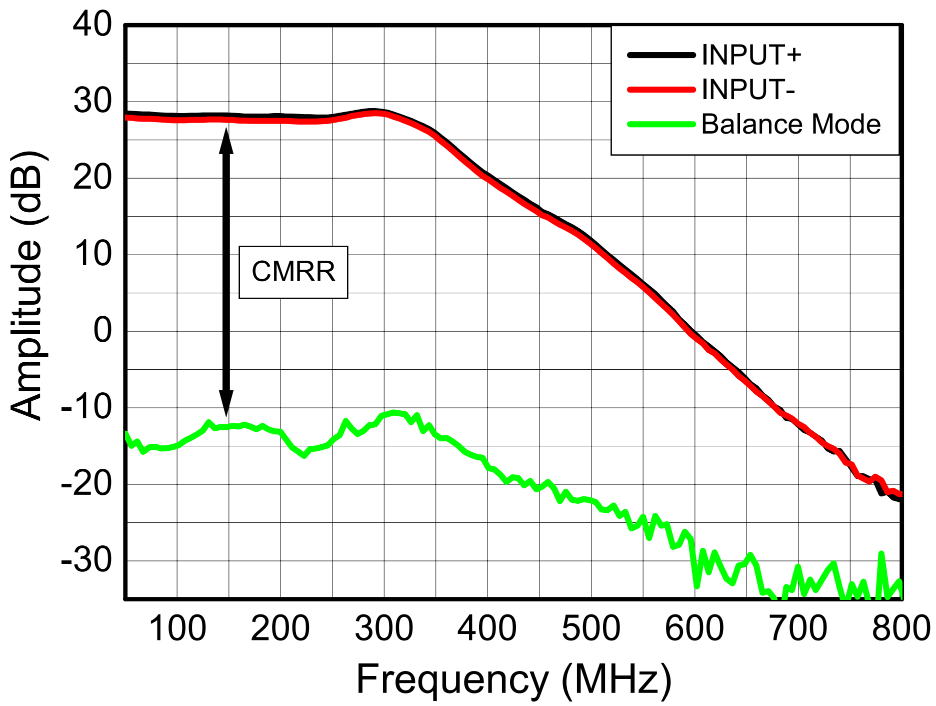


Figure 14: PDB130A Frequency response

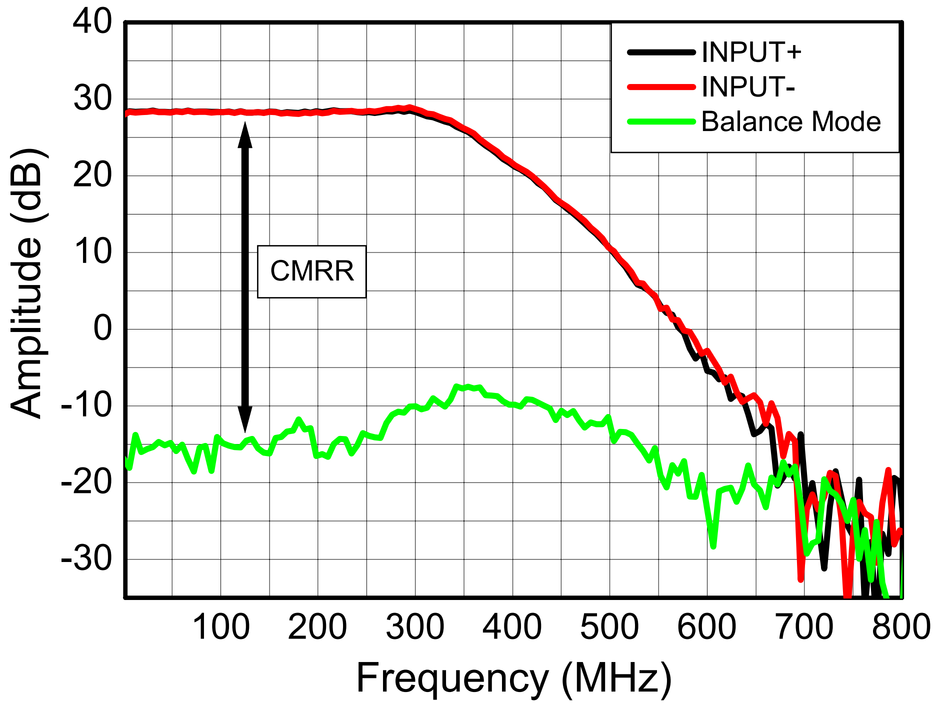


Figure 15: PDB130C Frequency response

Figure 16 and Figure 17 show typical noise spectra of PDB130x (RF OUTPUT) measured using electrical spectrum analyzer (RBW 100 kHz, Video BW 1 kHz). The INPUTs of the PDB130x were blocked. The lower curve is measured with the same setup and PDB130x switched off , i.e., it represents the measurement system's noise floor.

Model PDB130A has a minimum noise-equivalent power (NEP) of 14.7 pW/√Hz and PDB130C - 7.4 pW/√Hz from DC-100 MHz. The difference is caused by different detector responsivities. The integrated noise from DC-350 MHz is 660 nW_{RMS} for model PDB130A and 265 nW_{RMS} for PDB130C. This input optical noise level is the approximate minimum optical signal that can be detected with these models. For PDB130, the overall output voltage noise (V_{RMS}) across a 50 Ohm load is 2 mV_{RMS}.

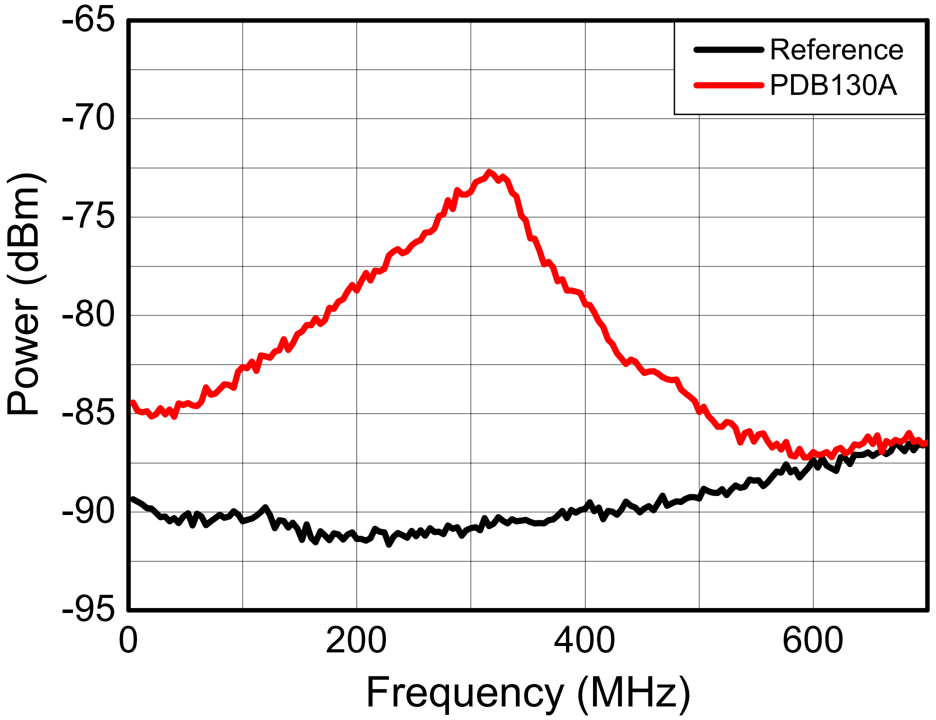


Figure 16: PDB130A spectral noise

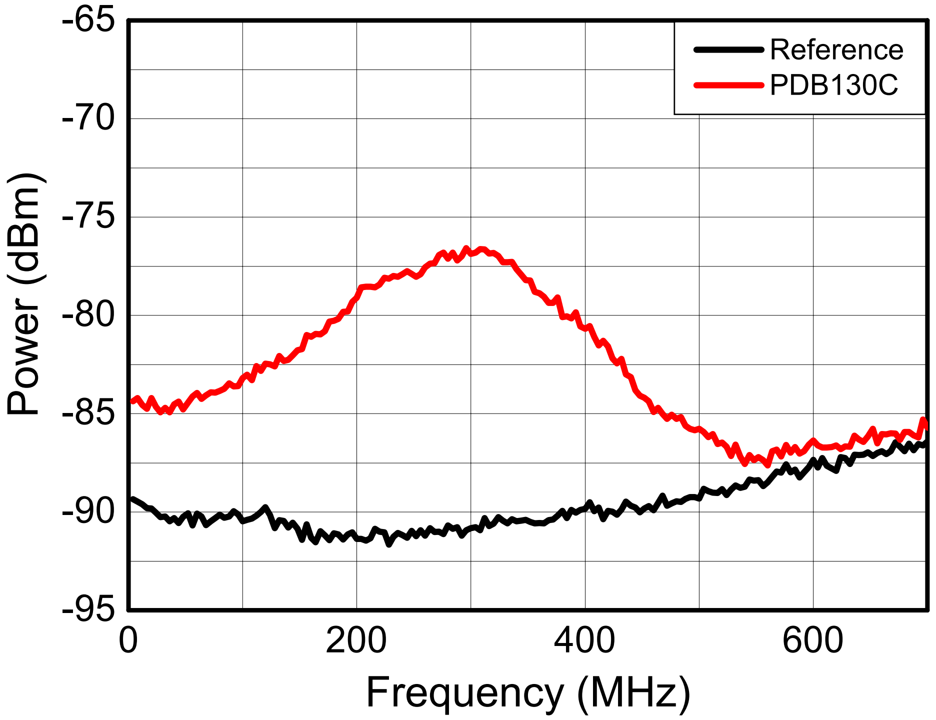


Figure 17: PDB130C spectral noise

3.5.4 Model PDB140

The PDB140 amplifier's transimpedance gain is 560×10^3 V/A for high impedance loads and 280×10^3 V/A into 50 Ω load. Depending on wavelength responsivity of the detector, the amplifier will reach saturation if the difference between the two optical input signals is greater than 12 µW for model PDB140A and 6.5 µW for PDB140C. The 3 dB bandwidth of the RF OUTPUT is 15 MHz. Model PDB140 contains an additional active low-pass aliasing filter section. Figure 18 and Figure 19 show typical frequency response curves for models PDB140A and PDB140C. For measurement setup see chapter 3.7.

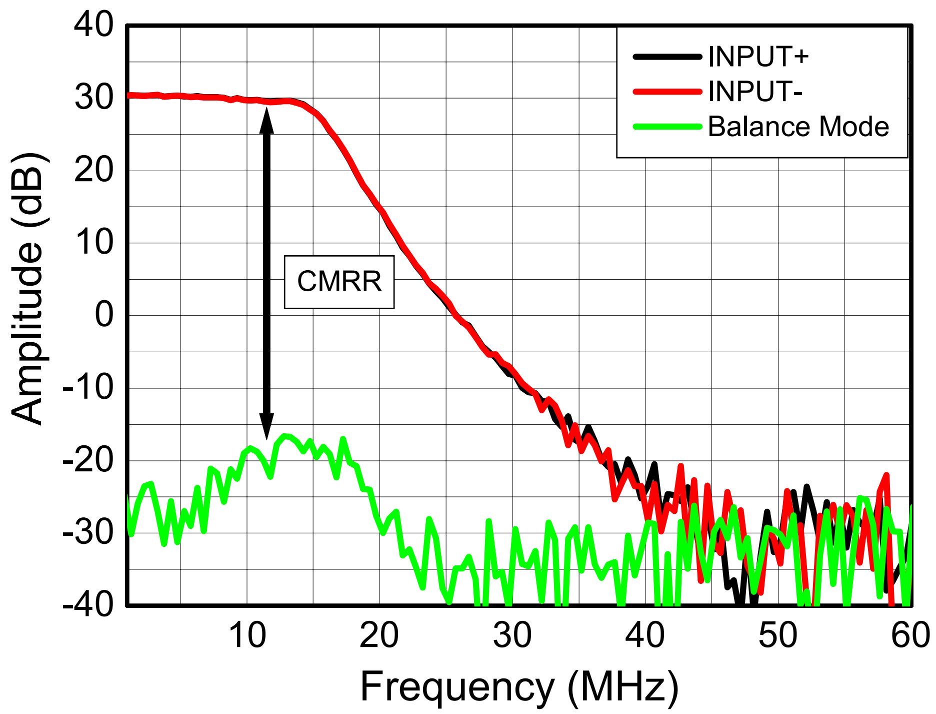


Figure 18: PDB140A Frequency response

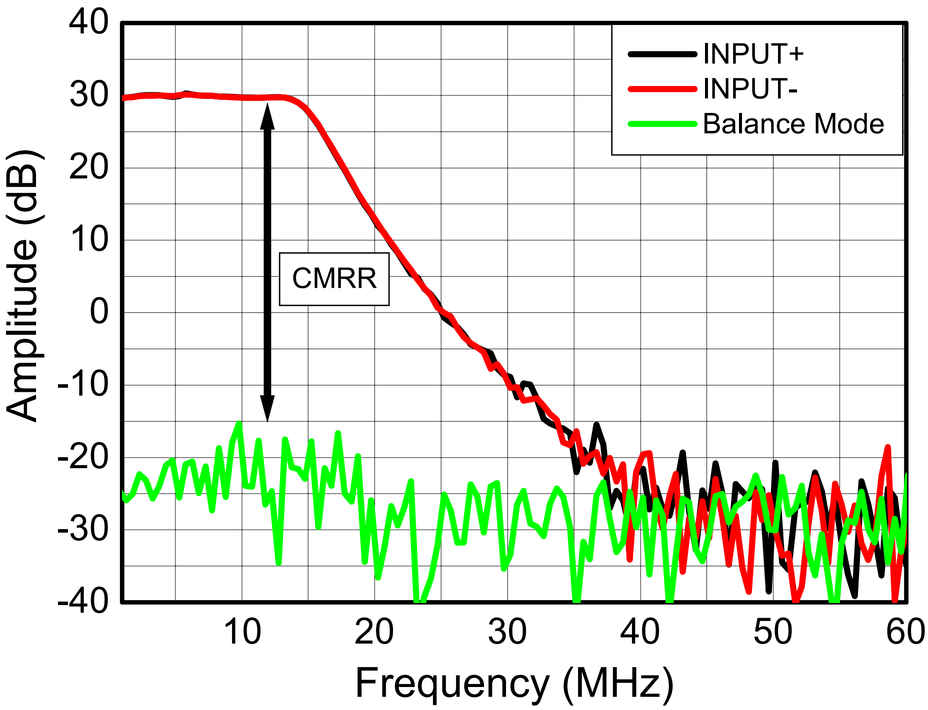


Figure 19: PDB140C Frequency response

Figure 20 and Figure 21 show typical noise spectra of PDB140x (RF OUTPUT), measured using electrical spectrum analyzer (RBW 100 kHz, Video BW 10 kHz). The INPUTs of the PDB140x were blocked. The lower curve is measured with the same setup and PDB140x switched off , i.e., it represents the measurement system's noise floor.

Model PDB140A has a minimum noise-equivalent power (NEP) of 5.7 pW/√Hz, PDB140C - 3.2 pW/√Hz from DC-10 MHz. The difference is caused by different detector responsivities. The integrated noise from DC-15 MHz is 21 nW_{RMS} for model PDB140A and 13 nW_{RMS} for PDB140C. This input optical noise level is the approximate minimum optical signal that can be detected with these models. For PDB140, the overall output voltage noise (V_{RMS}) across a 50 Ohm load is 3.9 mV_{RMS}.

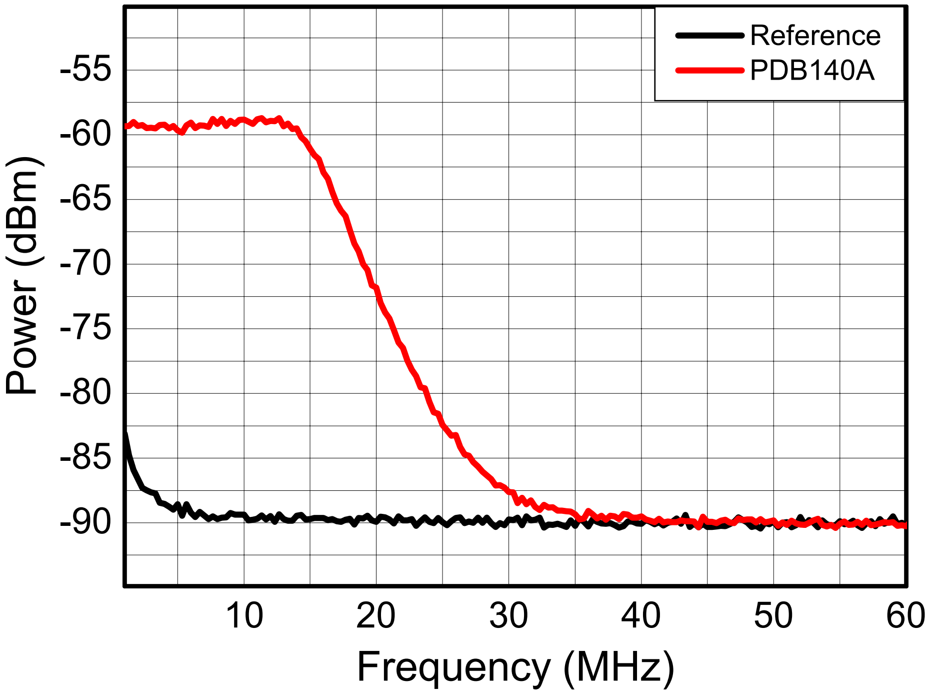


Figure 20: PDB140A spectral noise

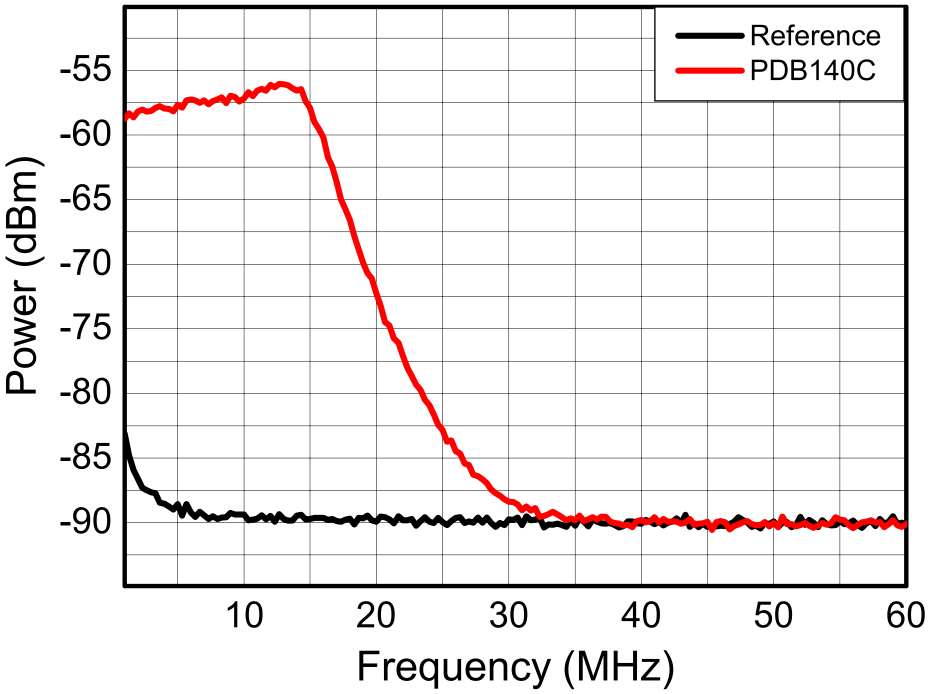


Figure 21: PDB140C spectral noise

3.5.5 Model PDB145

The PDB145 amplifier's transimpedance gain is $51x10^3$ V/A for high impedance loads and $25.5x10^3$ V/A into 50 Ω load. Depending on wavelength responsivity of the detectors, the amplifier will reach saturation if the difference between the two optical input signals is greater than 130 µW for model PDB145A and 70 µW for model PDB145C.

The 3 dB bandwidth of the RF OUTPUT is 15 MHz. Figure 22 and Figure 23 show typical frequency response curves of PDB145A and PDB145C. For measurement setup see chapter 3.7.

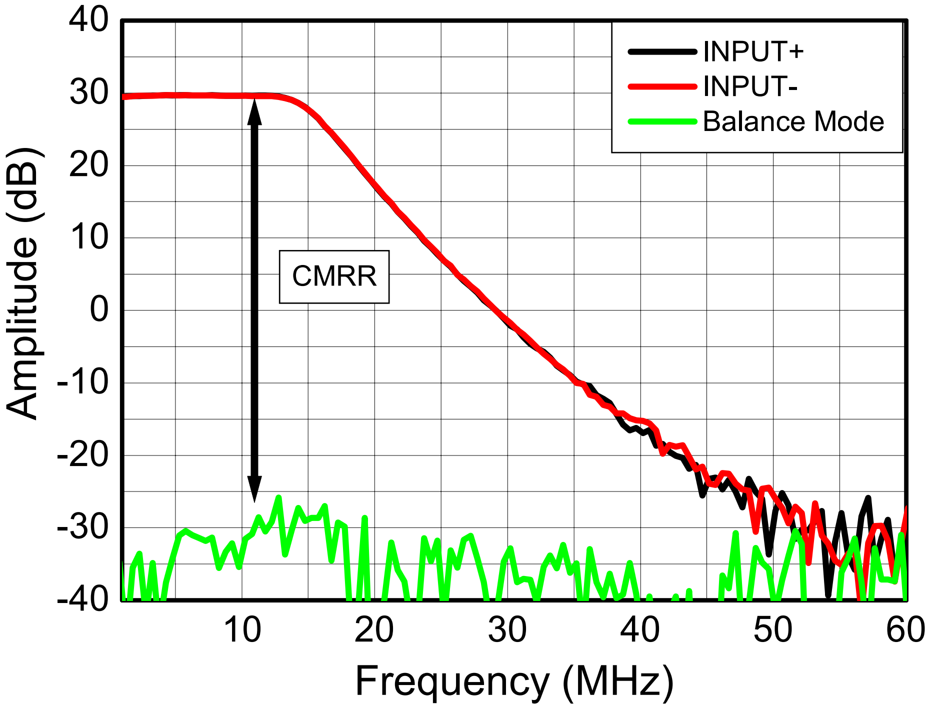


Figure 22: PDB145A Frequency response

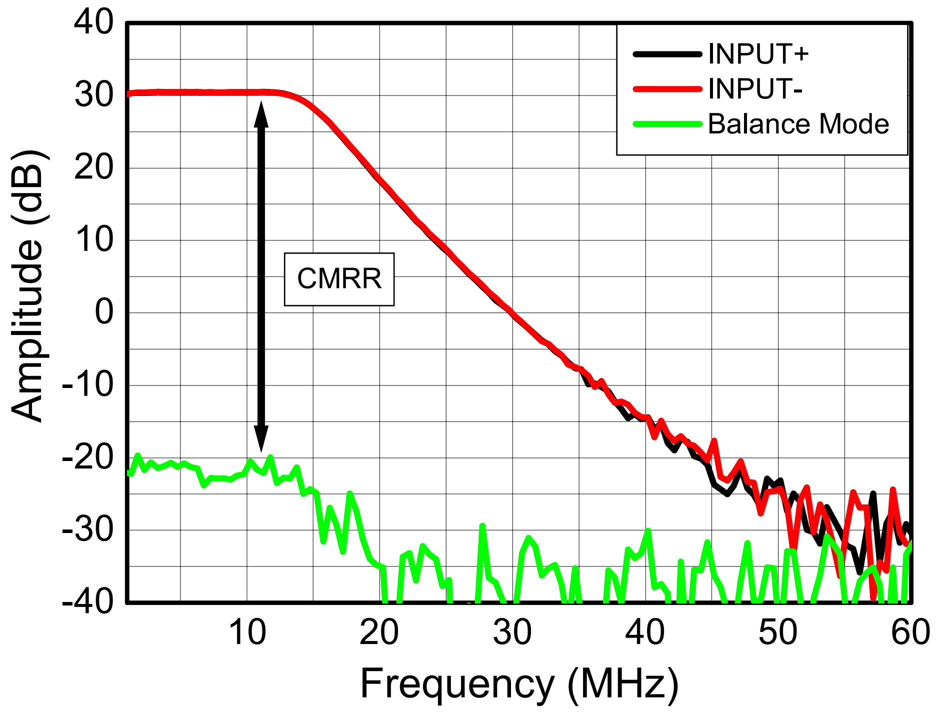


Figure 23: PDB145C Frequency response

Figure 24 and Figure 25 show typical noise spectra of PDB145x (RF OUTPUT), measured using electrical spectrum analyzer (RBW 100 kHz, Video BW 10 kHz). The INPUTs of the PDB145x were blocked. The lower curve is measured with the same setup and PDB145x switched off , i.e., it represents the measurement system's noise floor.

Model PDB145A has a minimum noise-equivalent power (NEP) of 5.7 pW/√Hz, PDB145C - 3.2 pW/√Hz from DC-10 MHz. The difference is caused by different detector responsivities. The integrated noise from DC-15 MHz is 22 nW_{RMS} for model PDB145A and 12 nW_{RMS} for PDB145C. This input optical noise level is the approximate minimum optical signal that can be detected with these models. For PDB145, the overall output voltage noise (V_{RMS}) across a 50 Ohm load is 0.37 mV_{RMS}.

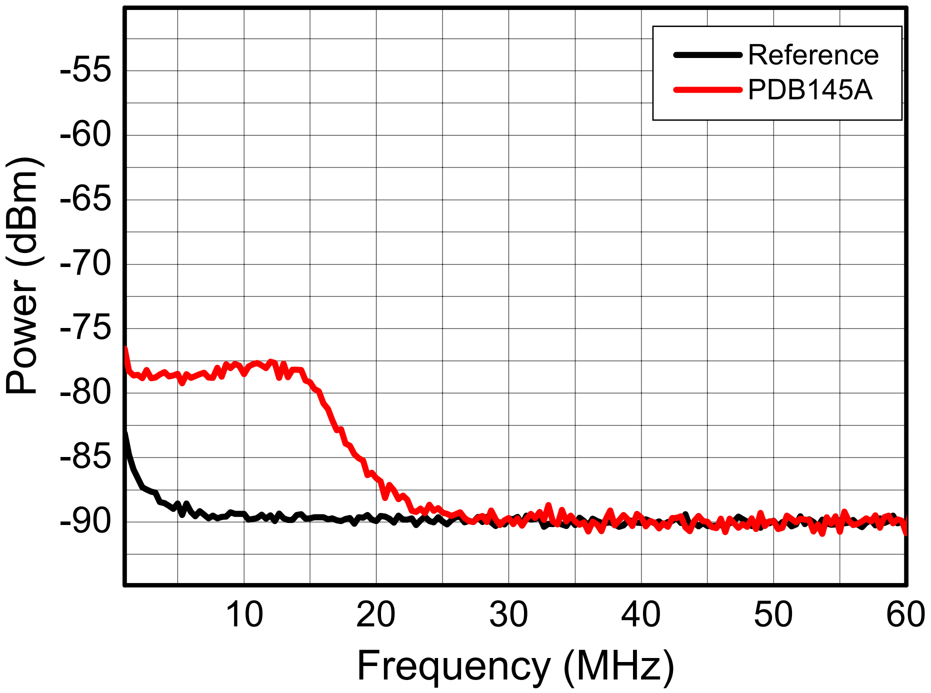


Figure 24: PDB145A spectral noise

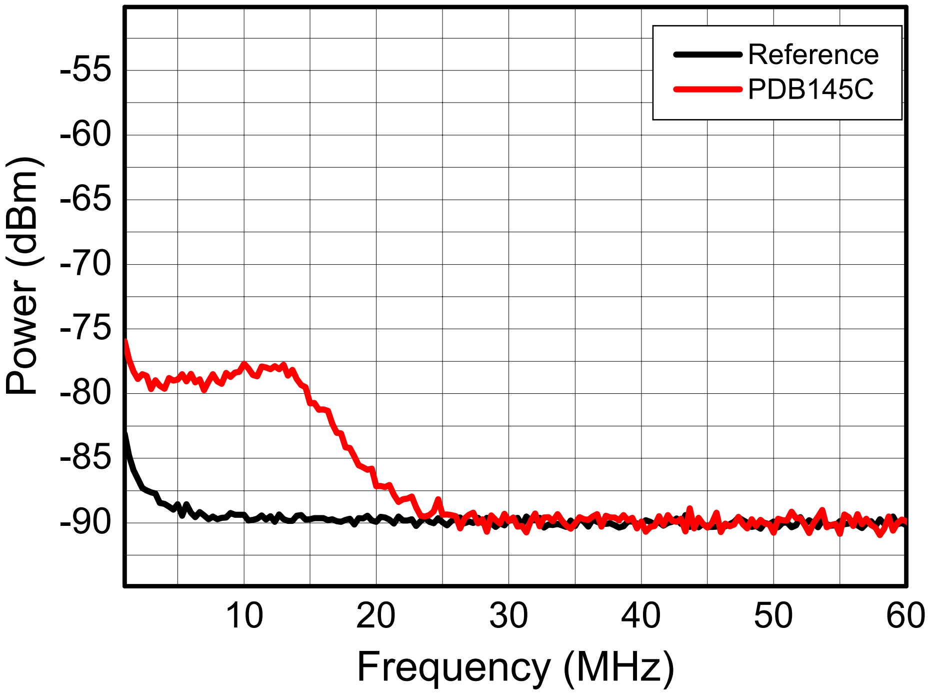


Figure 25: PDB145C spectral noise

3.5.6 Model PDB150

Model PDB150 is the switchable gain version of the PDB100 series. Transimpedance gain can be set by a five position rotary switch from 10^3 – 10^7 V/A. Effective transimpedance gain is reduced by a factor of two with 50 Ohm load.

Depending on wavelength responsivity of the detectors, the amplifier reaches saturation if the power difference between two optical input signals is greater than 10 mW (PDB150A) resp. 5 mW (PDB150C); these values are given for minimal gain (10^3) and will decrease accordingly with increasing gain.

For model PDB150 the maximum output voltage swing of the RF OUTPUT is ±5.8 V for high impedance loads and ±3 V into 50 Ω load at 10^3 / 10^4 / 10^5 / 10^6 V/A transimpedance gain. At highest transimpedance gain setting (10^7 V/A) RF OUTPUT voltage swing is ±9 V for high impedance loads and ±4.5 V into 50 Ω.

The 3 dB bandwidth of the RF OUTPUT at lowest transimpedance gain setting (10^3 V/A) is typically in excess of 150 MHz. Figure 26 and Figure 27 show typical frequency response curves for models PDB150A and PDB150C at different gain settings. For measurement setup see chapter 3.7.

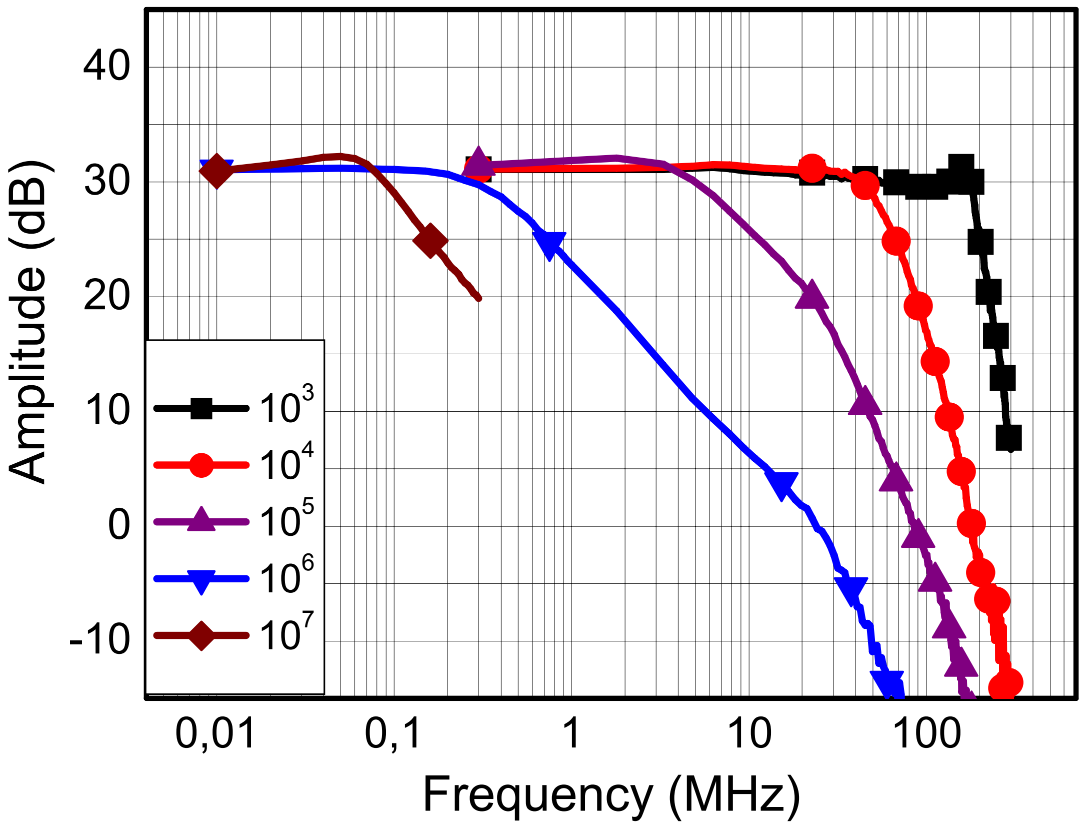


Figure 26: PDB150A Frequency response at different gain settings

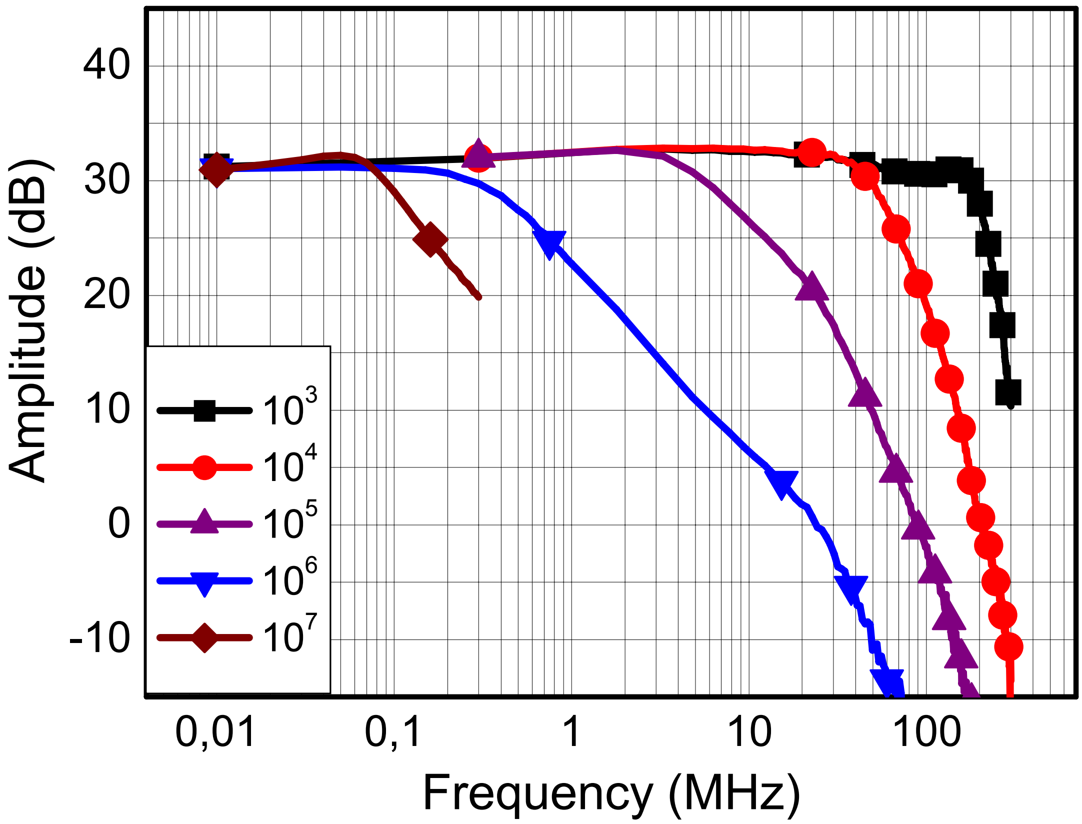


Figure 27: PDB150C Frequency response at different gain settings

Figure 28 and Figure 29 show typical noise spectra of PDB150x (RF OUTPUT) for different gain settings, measured using electrical spectrum analyzer (RBW 100 kHz, Video BW 1 kHz). The INPUTs of the PDB150x were blocked.
At highest transimpedance gain setting (10^7 V/A) model PDB150A has a minimum noise-equivalent power (NEP) of 0.6 pW/√Hz, PDB150C has a minimum NEP of 0.3 pW/√Hz. The difference is caused by different detector responsivity. The overall output voltage noise (V_{RMS}) depends on actual gain setting, see table below.

Transimpedance Gain	RF OUTPUT voltage noise V_{RMS} @ 50 Ohm load
10^3	0.60 mV
10^4	0.90 mV
10^5	1.22 mV
10^6	1.22 mV
10^7	2.05 mV

Note: When monitor ports are used, make sure that transimpedance gain is set in such way, that RF output is below saturation threshold.

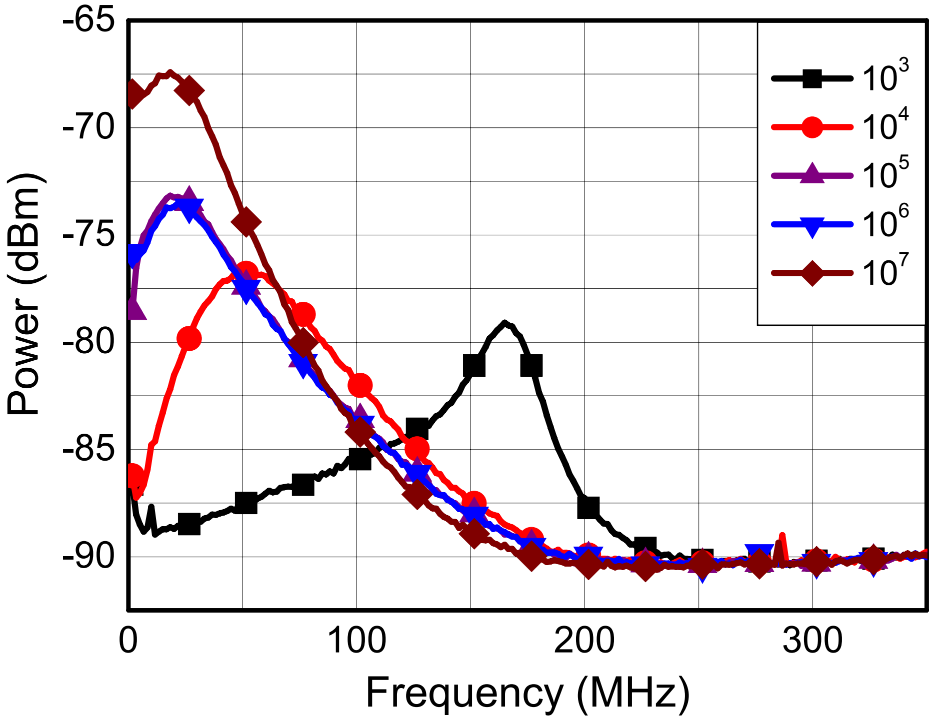


Figure 28: PDB150A spectral noise at different gain settings

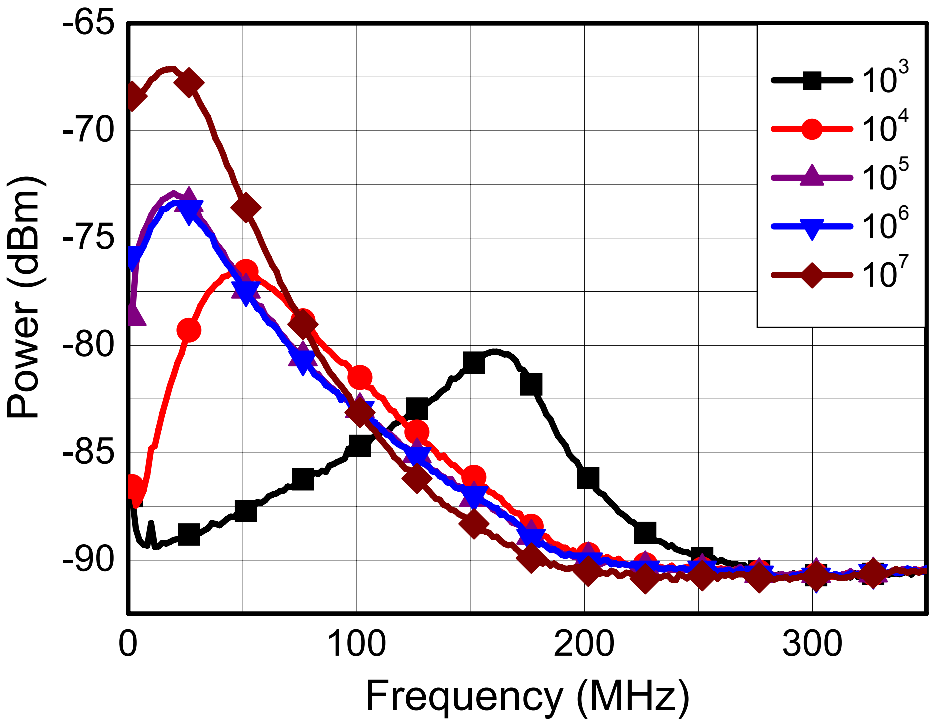


Figure 29: PDB150C spectral noise at different gain settings

NOTE

When monitor ports are used, make sure that transimpedance gain is set in such way, that RF output is below saturation threshold.

3.6 AC-coupling of the RF OUTPUT

Beside the standard DC coupling of the RF OUTPUT, AC coupled versions for any model of PDB100 series are available on request. AC coupling blocks the CW component (the unmodulated part) of the optical input signal. However, large CW components of the optical input signal will decrease linearity of the detectors.

AC coupling helps to improve the measurement capabilities in applications, where a comparably weak frequency modulated signal shall be measured on a strong CW background signal, which could saturate the amplifier. With AC coupling, equalizing of CW power levels on both inputs is not mandatory for noise cancellation. However, for optimal noise suppression the signal of interest (e.g. the modulated part) should be well balanced. AC coupling is also recommended when using the balanced detector in combination with a chopper and lock-in amplifier to further decrease noise level.

Therefore lower cut-off frequency is optimized to work with chopper frequencies down to 100 Hz. Figure 30 shows the comparison of AC and DC coupled RF Output signals when modulating the input signal with a mechanical chopper at a frequency of 500 Hz. (Note: Input signal for AC coupling was increased by factor 2 to allow direct waveform comparison)

Measurement bandwidth of the RF OUTPUT is not affected by AC coupling. Noise figures at lower frequencies are increased, see Figure 31.

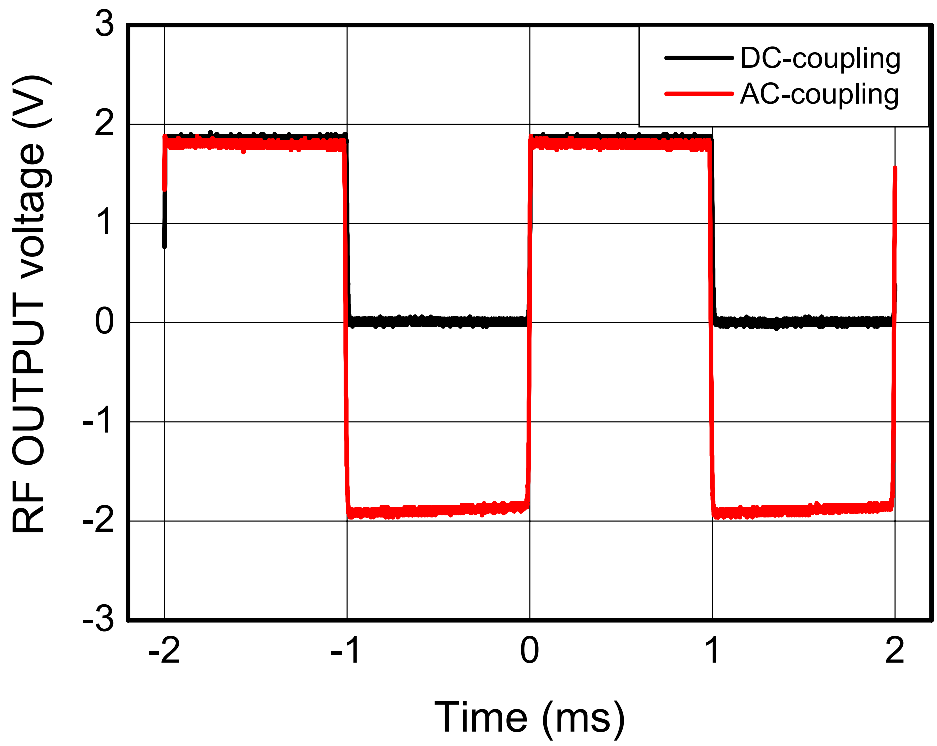


Figure 30: PDB110A waveform comparison for DC- and AC-coupling

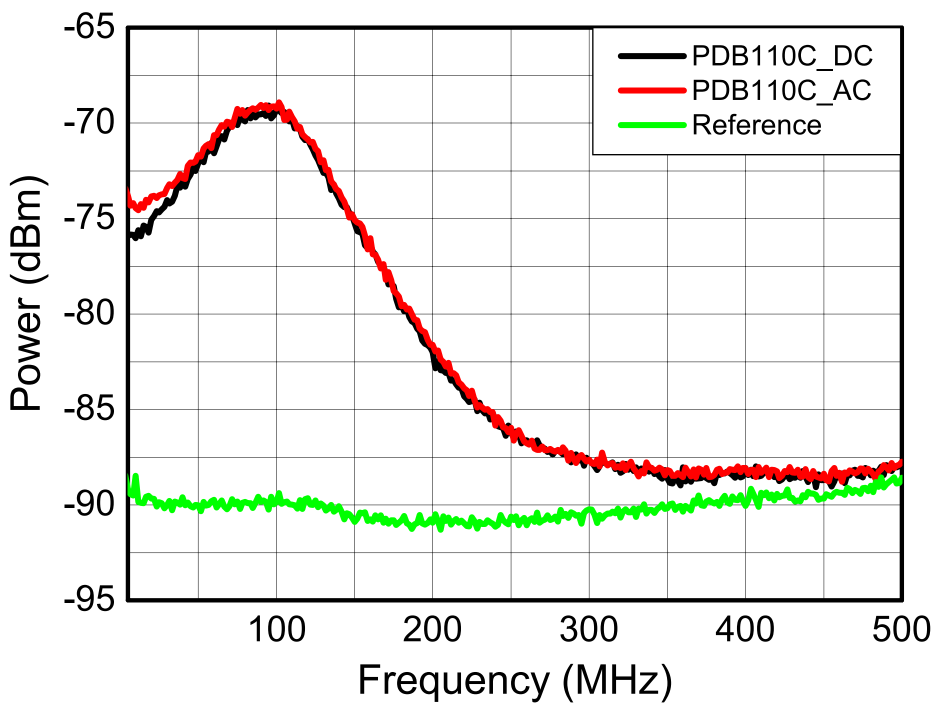


Figure 31: PDB110A spectral noise comparison for DC- and AC-coupling

3.7 Measuring CMRR Performance

The following section describes a basic setup to evaluate the functionality of the PDB100 series balanced detectors, especially the common mode noise suppression ability, AKA common mode rejection ratio (CMRR). In this experiment a common mode signal is generated, which is canceled out when the PDB1xx is used in balanced mode. The setup is shown in Figure 32.

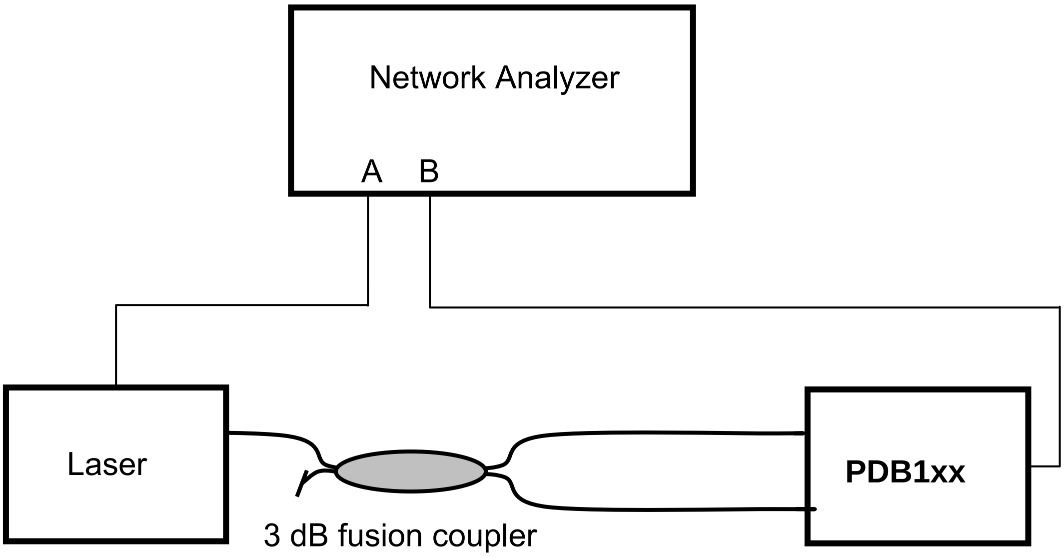


Figure 32: Basic setup for evaluation of CMRR performance

A network analyzer is used to measure the frequency dependent response of the PDB1xx. A pigtailed laser diode light source is the transmitter which is directly modulated by the network analyzers Port A. The modulated light is divided into two paths by a 3 dB fusion coupler. The coupler outputs are connected to both inputs of PDB1xx balanced amplified photodetector. The RF OUTPUT of PDB1xx is connected to the network analyzers Port B. Due to the modulation of the transmitter a common mode signal is generated which is suppressed by the PDB1xx.

The frequency response of each INPUT can be measured when only one coupler output is connected to INPUT. When both outputs of the fusion coupler, adjusted to exactly the same optical output power are connected to both inputs, the frequency dependent common mode rejection can be measured. The common mode rejection ratio CMRR can be calculated from the measured data with respect to the frequency response. Typical measurement curves for model PDB110A and PDB110C are shown in Figure 33 and Figure 34.

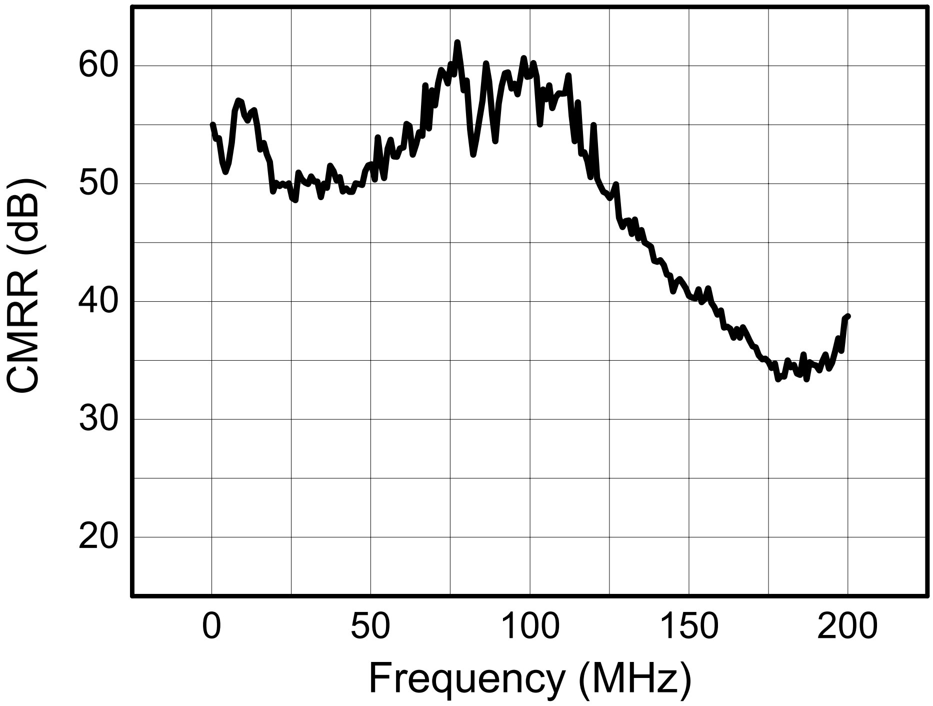


Figure 33: PDB110A Typical CMRR

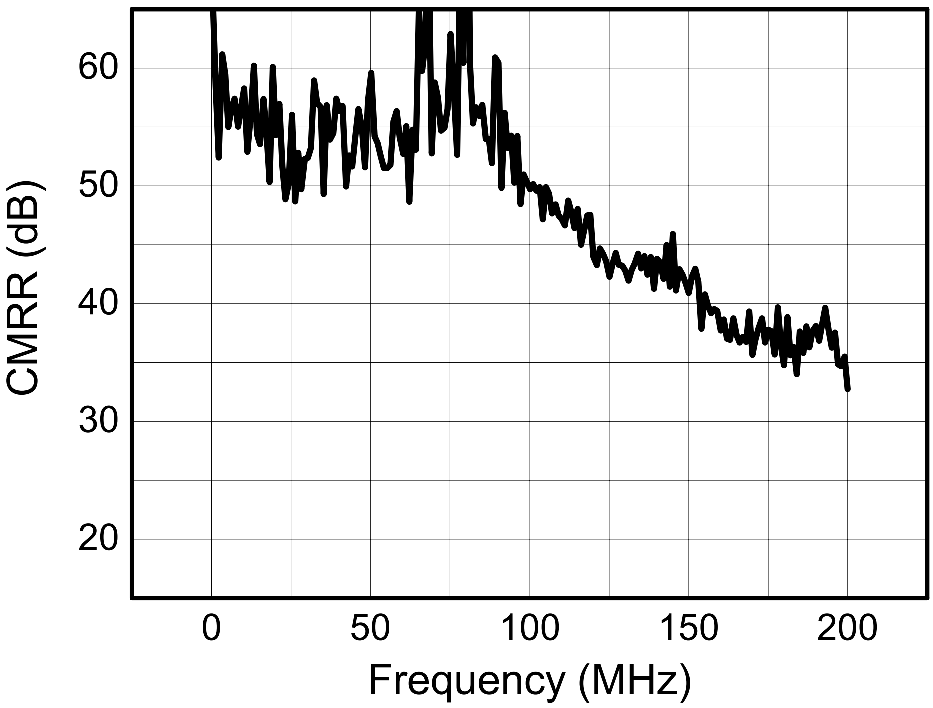


Figure 34: PDB110C Typical CMRR

3.8 Recommendations

Thorlabs PDB100 series Balanced Amplified Photodetectors can eliminate noise sources to allow precise measurements. The PDB100 series is designed to be used in a dual beam setup: one optical path for measurement and one invariant reference path. If set up properly, the PDB100 series can reduce common mode noise for more than 35 dB over the specified frequency range.

To obtain maximum possible common mode rejection (common mode noise suppression), equal power levels on each photodetector are essential. Any power imbalance will be amplified and hence decrease the possible noise reduction. One easy way to cancel out small power imbalances in a fiber based setup is to move in/out the FC connector within the FC input receptacle.

Equal optical path lengths are very important for common mode noise suppression especially at high frequency. Any path length difference will introduce a phase difference between the two signals, which will decrease the noise reduction capability of the balanced detector.

Equal power densities on both detectors are important as well to obtain maximum possible common mode rejection. Always try to illuminate the whole active area of the detector to prevent nonlinearities. High power focused beams may lead to frequency response degradation, resulting in dramatically reduced common mode rejection.

Etalon effects must be avoided in the optical paths. Using angle polished optical connectors will greatly reduce etalon effects in a fiber based setup. Effects like residual frequency modulation, polarization noise, polarization wiggle or spatial modulation can also degrade common mode noise suppression. For further details contact Thorlabs. In general, reducing sources of differential losses in the optical paths (other than the measurement itself) will improve the common mode noise reduction.

4 Warranty Warranty

Thorlabs GmbH warrants material and production of the PDB100 series for a period of 24 months starting with the date of shipment. During this warranty period *Thorlabs GmbH* will see to defaults by repair or by exchange if these are entitled to warranty.
For warranty repairs or service the unit must be sent back to *Thorlabs GmbH (Germany)* or to a place determined by *Thorlabs GmbH* . The customer bears the shipping costs to *Thorlabs GmbH* , in case of warranty repairs *Thorlabs GmbH* will pay for return shipment back to the customer.
If no warranty repair is applicable the customer bears the costs for return shipment as well.
In case of shipment from outside EU applying customs fees, taxes etc. shall be paid by the customer.

Thorlabs GmbH warrants the hard- and software determined by *Thorlabs GmbH* for this unit to operate fault-free provided that they are handled according to our requirements. However, *Thorlabs GmbH* does not warrant a faulty free and uninterrupted operation of the unit, of the soft- or firmware for special applications nor this instruction manual to be error free. *Thorlabs GmbH* is not liable for consequential damages.

Restriction of warranty

The warranty mentioned before does not cover errors and defects being the result of improper treatment, software or interface not supplied by us, modification, misuse or operation outside the defined ambient conditions stated by us or unauthorized maintenance.

Further claims will not be consented to and will not be acknowledged. *Thorlabs GmbH* does explicitly not warrant the usability or the economical use for certain cases of application.

Thorlabs GmbH reserves the right to change this instruction manual or the technical data of the described unit at any time.

5 Service and Maintenance

☝ **Attention** ☝

Do not try to open the power supply or the detector! Dangerous or even lethal voltages inside.

To avoid damage, do not expose it to spray, liquids or solvents!

5.1 General Care

Protect the PDB100 series from adverse weather conditions. The PDB100 series is not water resistant.

5.2 Cleaning

To clean the PDB100 series housing, use a mild detergent and damp cloth. Do not soak the unit in water or use solvent based cleaners.
When cleaning the windows of the photodetectors, please remember that is a sensitive optical device. Gently blow off any debris using compressed air and wipe gently with an optic tissue wetted with propane. It is recommended to remove the FC adaptors before cleaning the detector windows.

5.3 Repair

There are no serviceable parts in the PDB100 series or power supply. The PDB100 series does not contain any components to be repaired by the user. If any malfunction should occur or you suspect a problem, please contact Thorlabs GmbH for repair return instructions.

6 Listings

6.1 Mechanical Drawings

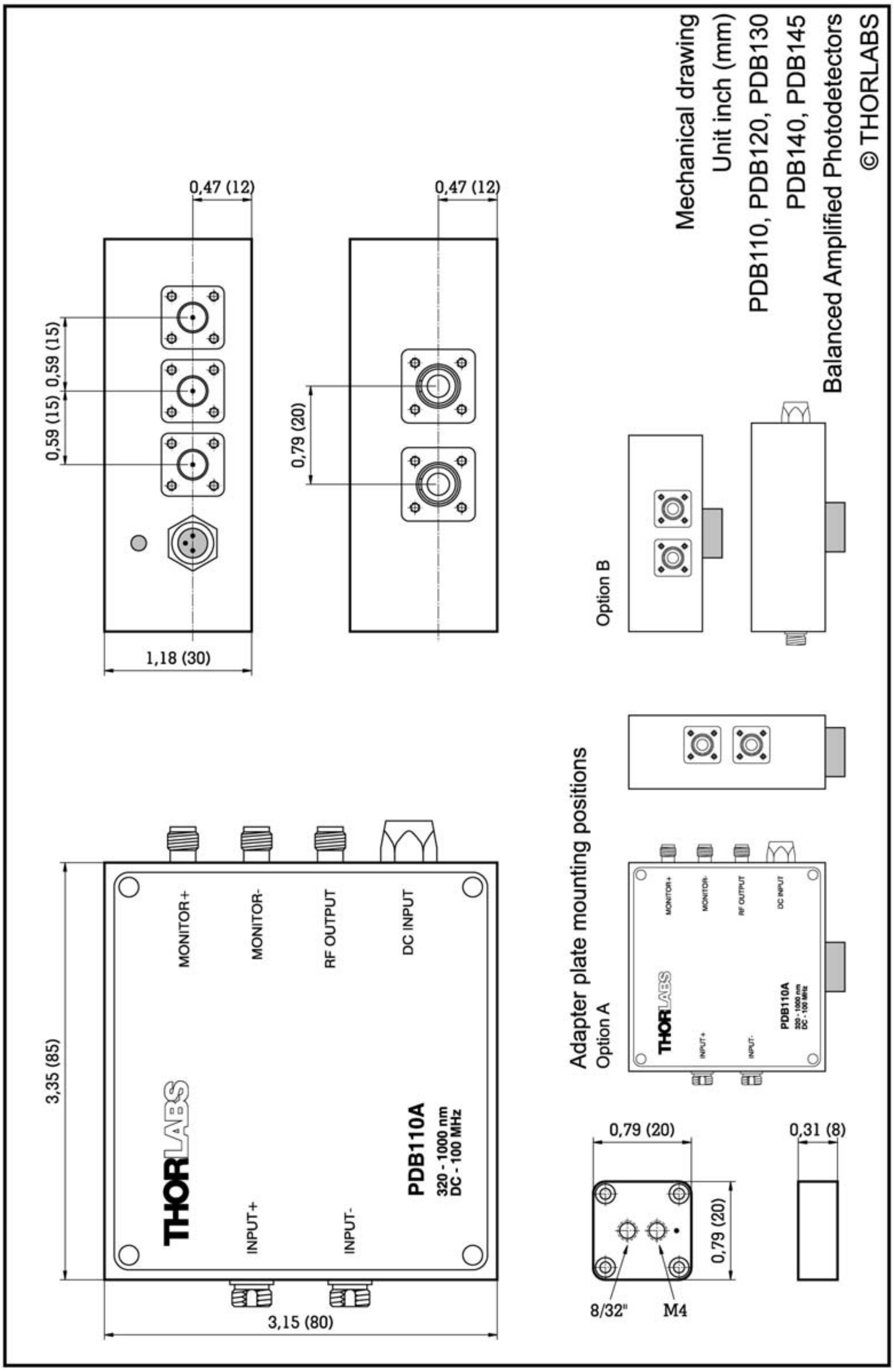


Figure 35: Mechanical drawing PDB110x, PDB120x, PDB130x, PDB14xx

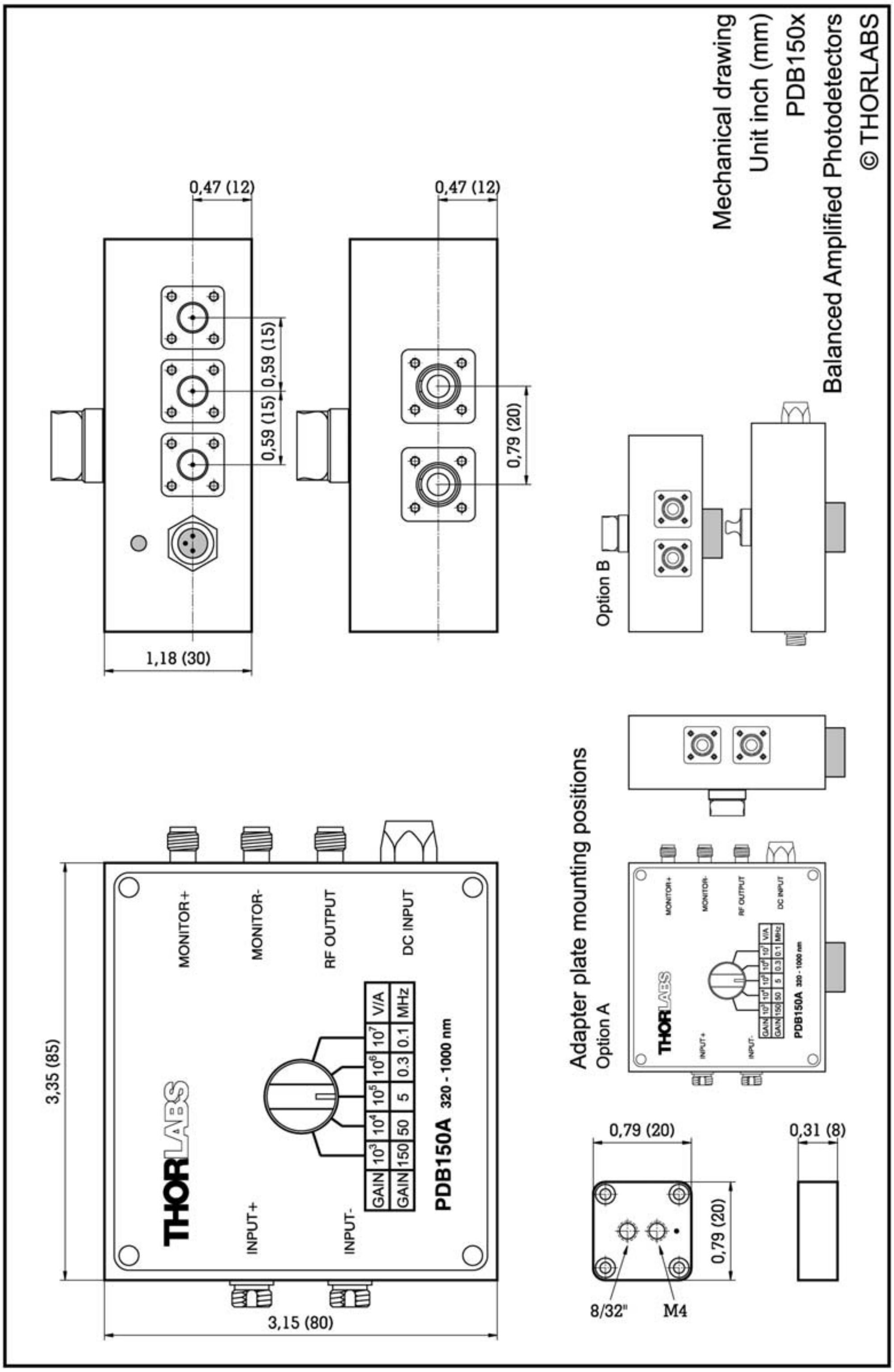


Figure 36: Mechanical drawing PDB150x

6.2 List of figures

6.3 Certifications and compliances

Certifications and compliances

Category	Standards or description	
EC Declaration of Conformity - EMC	Meets intent of Directive 89/336/EEC for Electromagnetic Compatibility. Compliance is given to the following specifications as listed in the Official Journal of the European Communities:	
	EN 61326	EMC requirements for Class A electrical equipment for measurement, control and laboratory use, including Class A Radiated and Conducted Emissions[1] and Immunity.[2]
	IEC 61000-4-2	Electrostatic Discharge Immunity (Performance criterion C)
	IEC 61000-4-3	Radiated RF Electromagnetic Field Immunity (Performance criterion B) [2]
Australia / New Zealand Declaration of Conformity - EMC	Complies with the Radiocommunications Act and demonstrated per EMC Emission standard[1,2,3]:	
	AS/NZS 2064	Industrial, Scientific, and Medical Equipment: 1992
FCC EMC Compliance	Emissions comply with the Class A Limits of FCC Code of Federal Regulations 47, Part 15, Subpart B[1].	

[1] Using high-quality shielded interface cables.
[2] Minimum Immunity Test requirement.

6.4 Thorlabs "End of Life" policy (WEEE)

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out "wheelie bin" logo (see fig. 15)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated

As the WEEE directive applies to self contained operational electrical and electronic products, this "end of life" take back service does not refer to other Thorlabs products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB's, housings etc.).

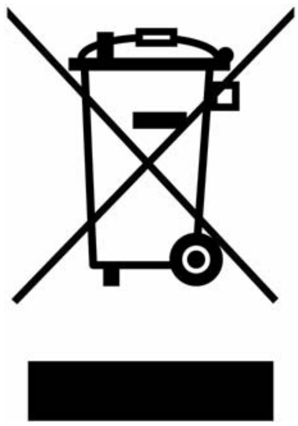
If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

6.4.1 Waste treatment on your own responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

6.4.2 Ecological background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.
The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of live products will thereby avoid negative impacts on the environment.



Crossed out “wheelie bin” symbol

6.5 Addresses

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Our company is also represented by several distributors and sales offices throughout the world.
Please call our hotline, send an E-mail to ask for your nearest distributor or just visit our homepage **http://www.thorlabs.com**