Balanced Amplified Photodetectors

PDB48xC-AC
Operation Manual

2014

Version: 1.2
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Contents

We aim to develop and produce the best solution for your application in the field of optical measurement technique. To help us to live up to your expectations and improve 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 hearing from you.

Thorlabs GmbH

Warning

Sections marked by this symbol explain dangers that might result in personal injury or death. Always read the associated information carefully, before performing the indicated procedure.

Attention

Paragraphs preceeded by this symbol explain hazards that could damage the instrument and the connected equipment or may cause loss of data.

Note

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

Please read these advices carefully!

1 General Information

Thorlabs PDB48xC-AC Balanced Amplified Photodetectors consist of two well-matched, fiber coupled photodiodes with length matched fibers and an ultra-low noise, ultra-low distortion high-speed transimpedance amplifier that generates an output voltage (RF OUTPUT) proportional to the difference between the photo current in the two photodiodes, i.e. the two optical input signals. Additionally, the unit has two fast monitor outputs (MONITOR+ and MONITOR-) to measure the individual optical input power level as well as low frequency (up to 3 MHz) modulated signals on each detector separately.

An adapter for post mounting can be attached to the bottom or side surface of the PDB48xC-AC housing. This adapter supports #8-32 as well as M4 post mounts.

The PDB48xC-AC is supplied with an external linear power supply.

The "Getting Started" 4 section gives an overview of how to set up the PDB48xC-AC Balanced Amplified Photodetectors. Subsequent sections contain detailed information about principle of operation, operating suggestions and technical specifications.

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 as it was designed for.
All modules must only be operated with proper shielded connection cables.
Only with written consent from *Thorlabs* may changes to single components be carried out or components not supplied by *Thorlabs* be used.
This precision device is only serviceable if properly packed into the complete original packaging including the plastic foam sleeves. If necessary, ask for a replacement package.

1.2 Ordering Codes and Accessories

PDB480C-AC 1.6 GHz, fixed gain, ultra-low distortion Balanced Amplified Photodetector with fiber length matched pigtailed InGaAs photo diodes, fiber SMF28

PDB481C-AC 1.0 GHz, fixed gain, ultra-low distortion Balanced Amplified Photodetector with fiber length matched pigtailed InGaAs photo diodes, fiber HI1060

2 Installation

This section is intended to provide information how to set up quickly the PDB48xC-AC Balanced Amplified Photodetectors. More details and advanced features are described in further sections.

2.1 Parts List

Inspect the shipping container for damage.

If the shipping container seems to be damaged, keep it until you have inspected the contents and you have inspected the PDB48xC-AC mechanically and electrically.

Verify that you have received the following items within the package:

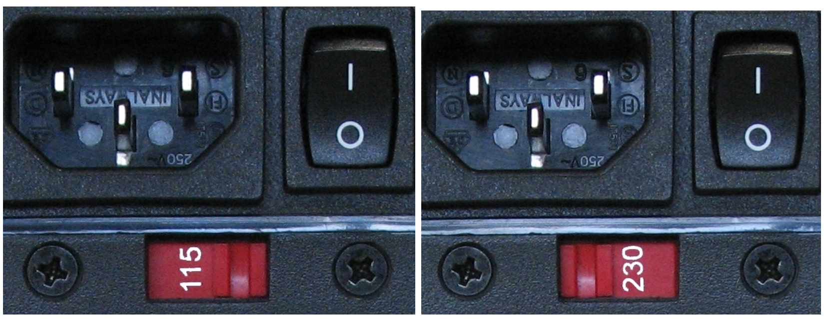
1. PDB48xC-AC Balanced Amplified Photodetector
2. Adapter Plate with four M2x8 screws and a hex key 1.5, for post-mounting the unit on a optical table
3. Power supply (±12V, 0.2A), switchable to 115V or 230V line voltage
4. Operation manual

2.2 Getting Started

Note

Please check prior to operation, if the indicated line voltage range on the power supply matches with your local mains voltage! If you want use your own power supply, Thorlabs offers an appropriate power connector cable.

- Carefully unpack the unit and accessories. If any damage is noticed, do not use the unit. Contact Thorlabs 22 and have us replace the defective unit.
- If required, mount the unit on your optical table or application. Therefore, 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. These threads can be used for mounting onto Thorlabs posts.
- Set the power supply to your local mains voltage (115 or 230 VAC):



- Connect the DC output cable of the power supply to the POWER IN jack.
- Connect the power supply to the AC outlet, turn power supply on
- Connect RF OUTPUT with coaxial cable to the data acquisition device. Please note, that a 50 Ω impedance device should be used for best RF performance.
- If necessary, connect monitor outputs (MONITOR+, MONITOR-) to measure the optical input power for each channel individually.

3 Operating Instruction

- Turn the power switch of the power supply to I. The green LED next to the DC input connector indicates correct power supply.
- Connect the optical source(s) to the optical input(s). Please note that the PDB48xC-AC is designed for FC/APC connectors!
- MONITOR outputs can be used for convenient alignment of a coarse input power balance. The maximum output voltage swing of the MONITOR outputs is 10V for high impedance loads. Saturation of the MONITOR outputs will occur at optical input power greater than 1 mW.
- The RF output signal must not exceed the maximum RF OUTPUT power at 1 dB compression (see Technical Data 12) to avoid saturation.
- For balanced operation illuminate both photodetectors simultaneously and use the MONITOR outputs to fine-tune the optical power balance by observing voltage on a digital voltmeter or other low-frequency measurement device.
- After finishing measurements, turn power off.

Attention

The damage threshold of the photo diodes is 10 mW (PDB480C-AC) resp. 5 mW (PDB481C-AC)! Exceeding this value will permanently destroy the detector!

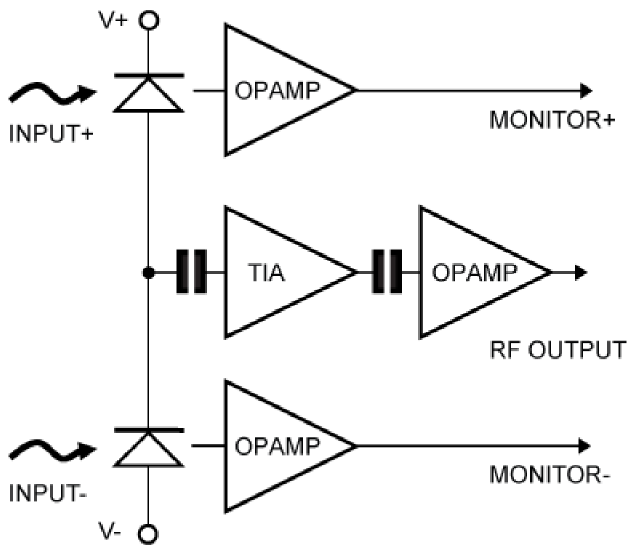
3.1 Operating Principle

Thorlabs PDB48xC-AC Balanced Amplified Photodetectors consist of two well-matched, pigtailed photodiodes and an ultra-low noise, ultra-low distortion high-speed transimpedance amplifier that generates an output voltage (**RF OUTPUT**) proportional to the difference between the photo currents of the two photodiodes, i.e. the difference between the two optical input signals.

Additionally, the unit has two monitor outputs (**MONITOR+** and **MONITOR-**) to observe the optical input power level on each photodiode separately. Due to their increased cut-off frequency, these outputs can also be used to measure low frequency modulated signals on each detector separately. This allows a signal normalization up to 3 MHz.

The PDB48xC-AC is powered by an external linear power supply (±12 V, 200 mA - included) via a PICO M8 power connector.

Below is a functional block diagram of the PDB48xC-AC Balanced Amplified Photodetectors:



3.2 Optical Inputs

The PDB48xC-AC comes with fiber-coupled optical inputs. Both photo detectors are SMF28 (PDB480C-AC) resp. HI1060 (PDB481C-AC) pigtailed and FC/APC connectorized. For this reason, a free space beam coupling directly to the PDB48xC-AC is not possible

The PDB48xC-AC can be used in balanced mode (both inputs are illuminated) as well as in single detector mode.

In order to avoid saturation, the output signal level should not exceed the RF output power 1-dB-compression point.

Attention

The damage threshold of the photo diodes is 10 mW (PDB480C-AC) resp. 5 mW (PDB481C-AC)! Exceeding this value will permanently destroy the photo diode!

Note

Take care for clean fiber connectors prior to attach them to the PDB48xC-AC's optical inputs! Clean and dust free connections are essential to minimize coupling loss and back reflections.

3.3 Electrical Outputs

The Thorlabs PDB48xC-AC has three SMA output connectors:

- **MONITOR +**
- **MONITOR -**
- **RF OUTPUT**

RF OUTPUT delivers an output voltage proportional to the difference between the photo currents of the two photodiodes This voltage can by calculated to:

$$U_{RF,OUT} = (P_{opt,1} - P_{opt,2}) \times \Re(\lambda) \times G$$

with: $\Re(\lambda)$ - responsivity of the photo diode at given wavelength

$P_{opt,1}$ and $P_{opt,2}$ - optical input power

G - transimpedance gain of the RF output

The responsivity $\Re(\lambda)$ for a given wavelength can be read from the individual curves in section Technical Data to estimate the **RF OUTPUT** voltage. Please note that the given responsivity curves represent typical values - individual responsivity may deviate.

The maximum **RF OUTPUT power** is typically + 18 dBm at 1 dB compression. To explain that: An ideal amplifier would be a linear device - it's gain is constant at any input power level. In reality, the output power of the amplifier is limited (e.g. by supply voltage). That means, with increased input power the amplifier becomes saturated. Before the saturation is reached, a reduction in gain takes place - the result is a compression effect. The 1 dB compression point is defined as the output power where the gain is 1 dB less than the small signal gain.

In order to avoid saturation, the output signal level should not exceed this 1-dB-compression point.

MONITOR Outputs

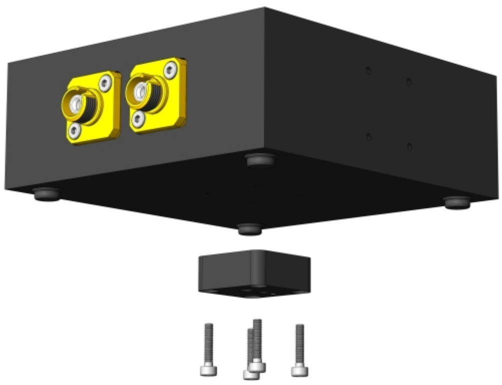
The signal monitor outputs (**MONITOR+** and **MONITOR-**) allow observation of the input power level and can be used as individual power indicators. These outputs can also be used to measure RF (up to 3 MHz) modulated signals on each detector separately. The maximum output voltage swing of the **MONITOR** output is +10 V for high impedance loads (+1.5 V into 50 Ω). Saturation of **MONITOR** outputs will occur at optical input power level greater than 1 mW, depending on the detector's wavelength response.

The amplifier offset voltage is factory set to zero at 23°C ambient temperature. A small drift during a short warm-up period (~5min) may occur. For exact DC light level measurements a constant temperature environment is recommended.

3.4 Mounting

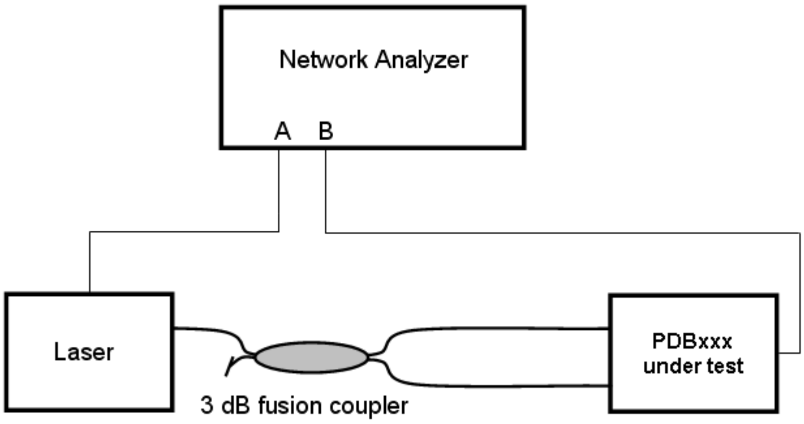
The PDB48xC-AC is housed in a rugged shielded aluminum enclosure.

For post mounting an adapter can be attached to the bottom or side surface using four M2x8 screws (see below). This adapter supports #8-32 as well as M4 post mounts. The M4 tread is marked.



3.5 CMRR and Frequency Response

An important specification for balanced amplifiers is it's ability to suppress common mode noise, which is reflected in the Common Mode Rejection Ratio (CMRR). In the setup as described below, the Device under Test (DuT) - here a PDB48xC-AC - is tested for CMRR. A common mode signal is generated, which is canceled out when the amplifier is in balanced mode.



A network analyzer is used as signal generator (output A) and receiver (input B) The receiver is synchronized with the signal generator and measures selectively at the same frequency. A laser light source is modulated by the signal generator (port A) and acts as transmitter. To the laser output a 3 dB fusion coupler is connected, splitting the modulated light signal into two paths. Depending on the measurement task, one or both coupler outputs are connected to the inputs of the DuT. The output of the DuT that should be measured is connected to the network analyzers Port B.

Frequency response measurements

The frequency response of each signal path can be measured by connecting only one coupler output to the appropriate input. This way, the frequency response curves of the RF OUTPUT from INPUT + and INPUT- can be measured, as well as the frequency responses of the MONITOR outputs, as shown in the individual technical data.

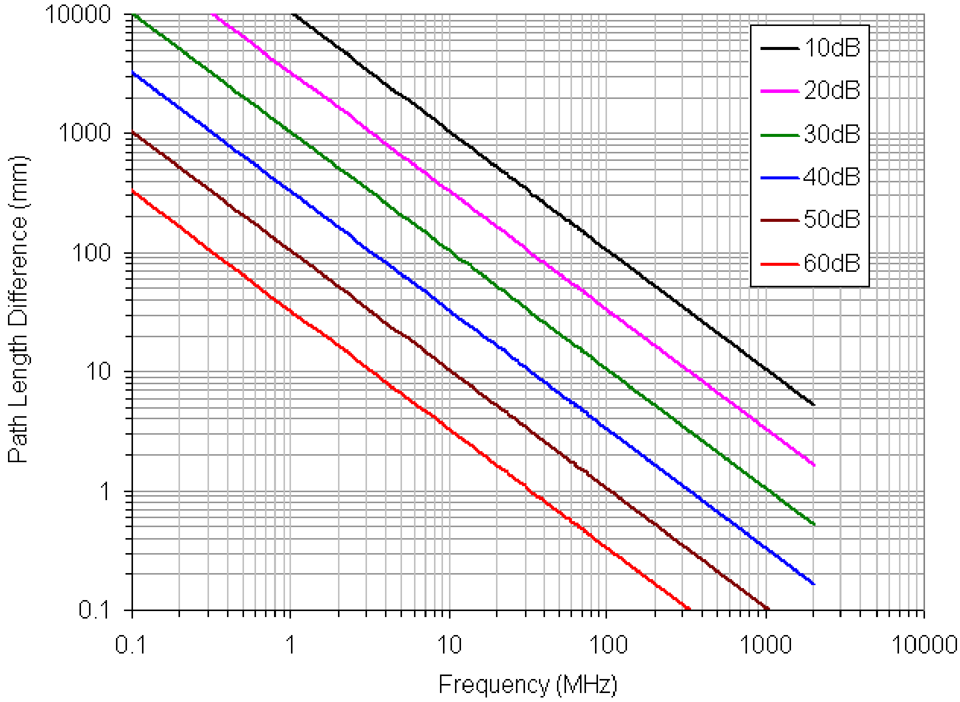
CMRR measurement

For Common Mode Rejection measurement, both outputs of the fusion coupler are connected to both inputs of the DuT. The optical power level at both inputs must be well matched ("balanced") in order to achieve the optimal common mode suppression. Now the common mode rejection can be measured as a function of frequency. The frequency response of the RF OUTPUT must be considered when calculating the CMRR - it is the difference between the RF OUTPUT signal at a given frequency and the measured common mode or balanced output signal - at the same frequency. Typical measurement curves can be found in the individual technical data.

3.6 Recommendations

Thorlabs PDB48xC-AC Balanced Amplified Photodetectors can eliminate noise sources to allow precise measurements. The PDB48xC-AC 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 PDB48xC-AC can reduce common mode noise for more than 25 dB over the specified frequency range. Below are given some recommendations to achieve an optimal common mode suppression:

- To obtain the 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.
- Equal optical path lengths are very important for common mode noise suppression especially at higher frequencies. Any path length difference will introduce a phase difference between the two signals, which will decrease the noise reduction capability of the balanced detector. The figure below shows the maximum allowed path length difference in fiber to obtain a desired CMRR.



- Avoid etalon effects (interference fringes caused between two optical surfaces) in 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.
- Another critical point can be electrostatic coupling of electrical noise associated with ground loops. In most cases an electrically isolated post (see Thorlabs parts TRE or TRE/M) will suppress electrical noise coupling. Always try to identify the electrical noise sources and increase the distance to the PDB48xC-AC Balanced Detector. Different common ground points can also be tested.

4 Maintenance and Service

Protect the PDB48xC-AC from adverse weather conditions. The PDB48xC-AC is not water resistant.

Attention

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

The unit does not need a regular maintenance by the user. It does not contain any modules and/or components that could be repaired by the user himself. If a malfunction occurs, please contact Thorlabs 22 for return instructions.

Do not remove covers!

To clean the PDB48xC-AC series housing, use a mild detergent and damp cloth. Do not soak the unit in water or use solvent based cleaners.

Cleaning of the fiber connectors

The photodiodes of the PDB48xC-AC are pigtailed with single mode fiber and connectorized by FC/APC connectors. Clean and dust-free surfaces of the ferrule tips are essential to minimize coupling losses. If the connectors are suspected to be soiled, the ferrule tips can be cleaned this way:

Remove the two screws (1), fixing the front part (2) of the switchable adapter. Detach the front part (2) an clean the ferrule tip using a lint-free tissue damped with alcohol or propanol. The ferrule receptacle of the front part (2) can be cleaned from dust using compressed air (duster).

When mounting the front adapter, take care for it's correct orientation: The cylindrical key of the front part must match with it's counterpart in the PDB48xC-AC's housing.

Warning

The screws (3), fixing the base of the switchable adapter to the housing, **must not be removed**!

5 Appendix

Comments and explanations to the individual specifications

- **Typical responsivity** is the responsivity $\Re(\lambda)$ of the photo diode at the stated wavelength.
- **Transimpedance [V/A]** is the ratio of output voltage to photo current, it is wavelength independent.
- **Conversion gain [V/W]** is the ratio of output voltage to input optical power, by other words

  $$G_{CONV} = G_{TRANS} \times \Re(\lambda)$$

  This formula shows, that the conversion gain is dependent on the actual wavelength. In specifications, it is given only for the indicated operating wavelength.
- **NEP** (Noise Equivalent Power) is stated for 30 kHz to 100 MHz frequency range.
- **Overall output voltage noise** [V_{RMS}] is the value which can be measured across a 50 Ω load at large bandwidth, e.g., if connect the RF output to a 50 Ω terminated scope input.
- **Max. input power** is the damage threshold of the photo diode.
- **Typical noise spectra** (diagrams): These spectra were measured using an electrical spectrum analyzer (resolution bandwidth 100 kHz, video bandwidth 10 kHz). The INPUTs of the balanced detectors under test were blocked. The lower curve in the diagram was measured with the same setup and the balanced detectors under test switched off, i.e., it represents the measurement system's noise floor.
- **Monitor outputs** are designed for use with high impedance loads (e.g., high-Z scope input etc.), but can also drive 50 Ω loads. Monitor outputs conversion gain is given for the indicated operating wavelength and high impedance load.
- **Typical frequency response curves** are measured using the setup described in section "CMRR and Frequency Response" 8

5.1 Technical Data

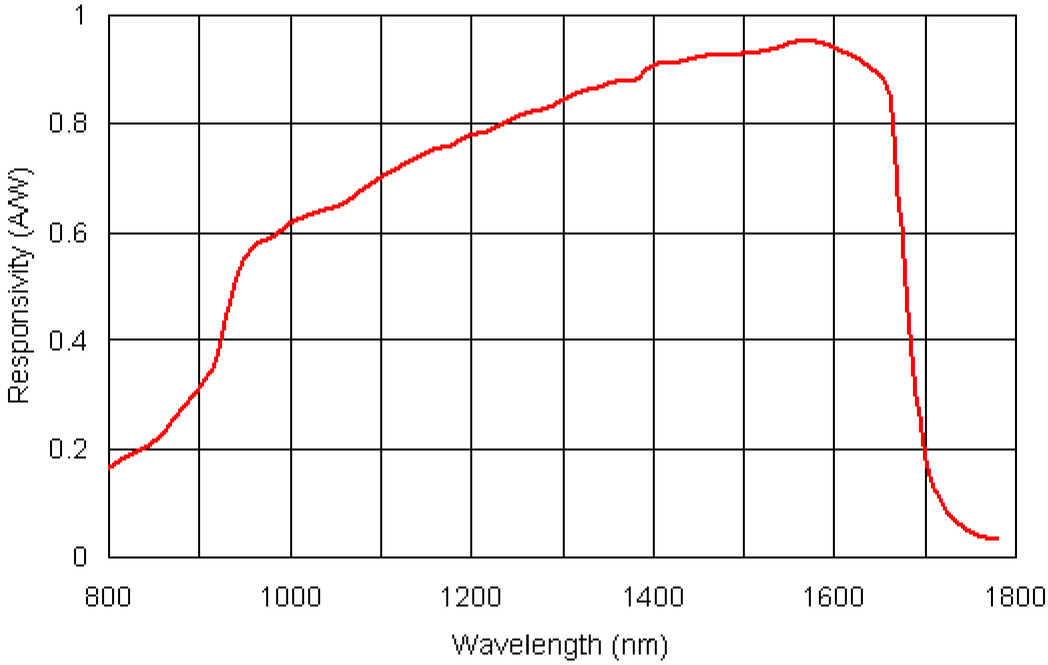
Item #	PDB480C-AC	PDB481C-AC
Detector		
Detector Type	InGaAs / PIN	
Optical Inputs	FC/APC **(SMF28e+ inside)**	FC/APC **(HI1060 inside)**
Coupling Loss	< 0.5 dB (typ. < 0.3 dB)	<1.0 dB (typ. < 0.4 dB)
Operating Wavelength	**1300 nm** (1200 - 1700 nm)	**1060 nm** (900 - 1400 nm)
Responsivity, typ.	0.9 A/W @ 1300 nm	0.72 A/W @ 1060 nm
Active Detector Diameter	0.075 mm	0.080 mm
Optical Back Reflection	< -40 dB	
Photo Diode Damage Threshold	10 mW	5 mW
RF OUTPUT		
RF OUTPUT Bandwidth (3dB)	30 kHz to 1.6 GHz	30 kHz to 1.0 GHz
Common Mode Rejection Ratio	>25 dB (typ. >30 dB)	
RF OUTPUT Transimpedance Gain 50 Ω load	16×10^3 V/A	
RF OUTPUT Conversion Gain 50 Ω load	14.4×10^3 V/W @ 1300 nm	11.5×10^3 V/W @ 1060 nm
RF OUTPUT Power at 1 dB compression 50 Ω load	min. +16.5 dBm typ. +18 dBm	
RF OUTPUT Coupling	AC coupling only	
RF Output Impedance	50 Ω	
Minimum NEP (30 kHz to 100 MHz)	9.3 pW/√Hz	9.0 pW/√Hz
Overall Output Voltage Noise	< 9 mV_{RMS}	< 6.5 mV_{RMS}
MONITOR Outputs		
MONITOR Output Impedance	200 Ω	
MONITOR Output Bandwidth (3 dB)	DC to 3 MHz	
MONITOR Output Conversion Gain High Z load	9 V/mW @ 1300 nm	7.2 V/mW @ 1060 nm
MONITOR Output Voltage Swing High Z load	max. 10 V	
Overall Output Voltage Noise	< 0.65 mV_{RMS}	
DC Offset	< ± 2 mV	
General		
Electrical Outputs	SMA	
DC Power Supply	± 12V @ 200mA	
Operating Temperature Range [1])	0 - 40 °C	
Storage Temperature Range	-40 to 70 °C	
Dimensions (W x H x D)	85 mm x 80 mm x 30 mm	
Weight	0.35	

[1]) non-condensing

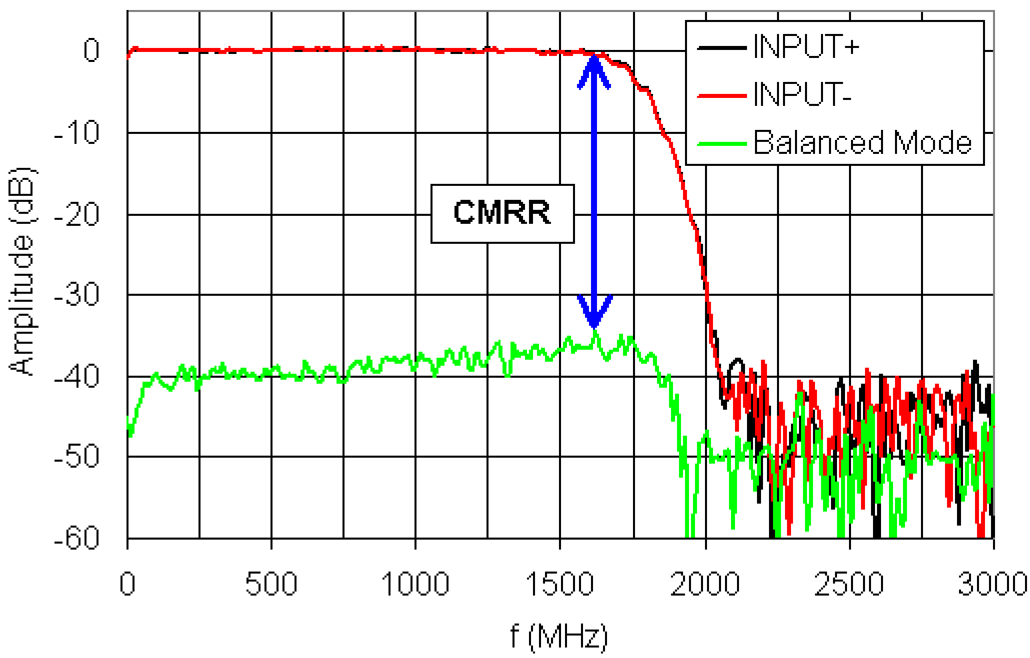
Values for transimpedance and conversion gain are lossless gain values, i.e., losses introduced by FC/APC connectors (typically 0.15 to 0.35 dB) are not considered.

All technical data are valid at 23 ± 5°C and 45 ± 15% rel. humidity (non condensing)

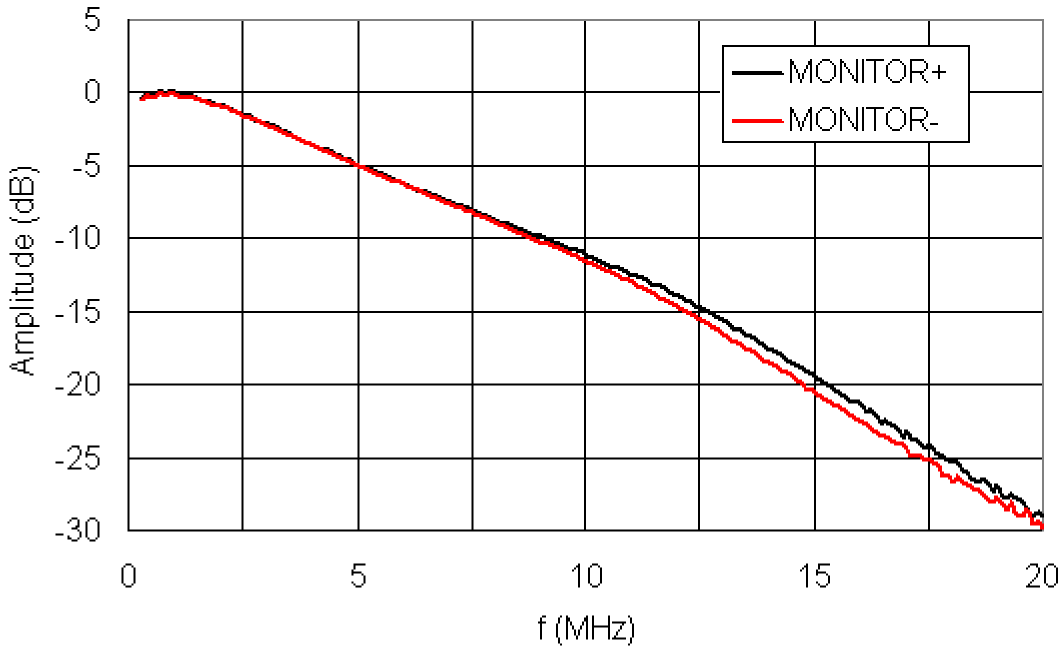
5.1.1 Individual Diagrams PDB480C-AC



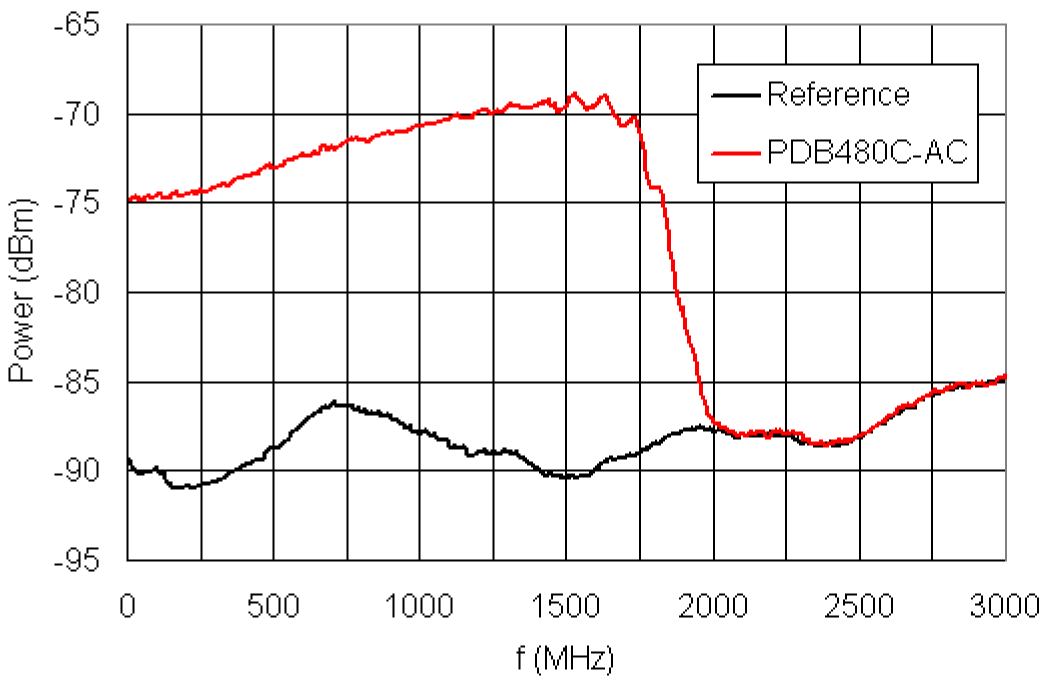
PDB480C-AC - Typical Detector Responsivity



PDB480C-AC - Typical RF OUTPUT Frequency Response

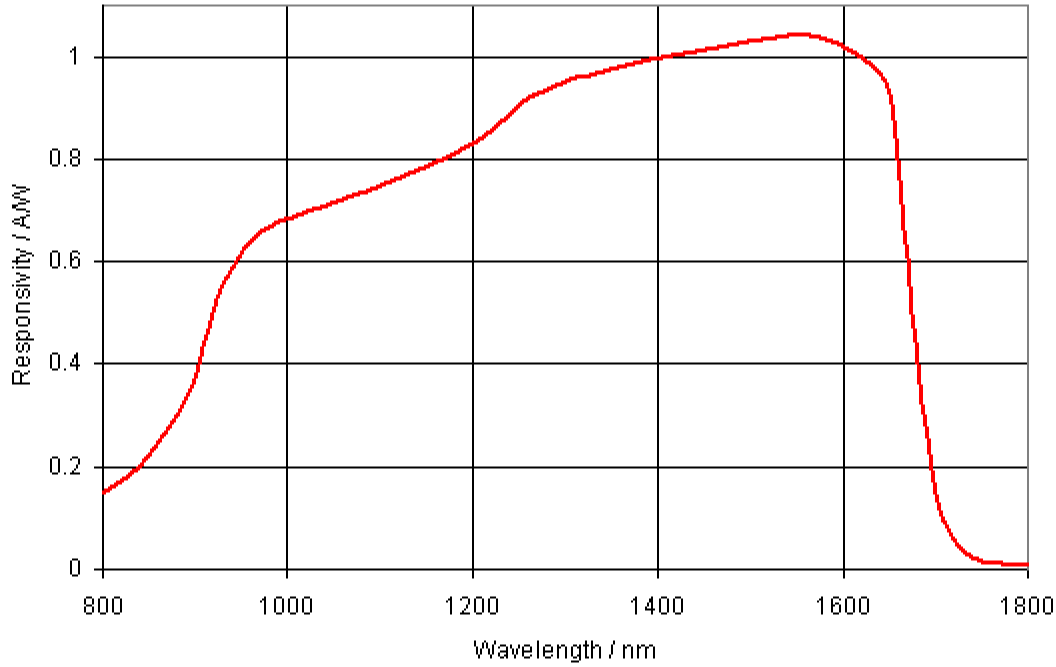


PDB480C-AC - Typical MONITOR Output Frequency Response

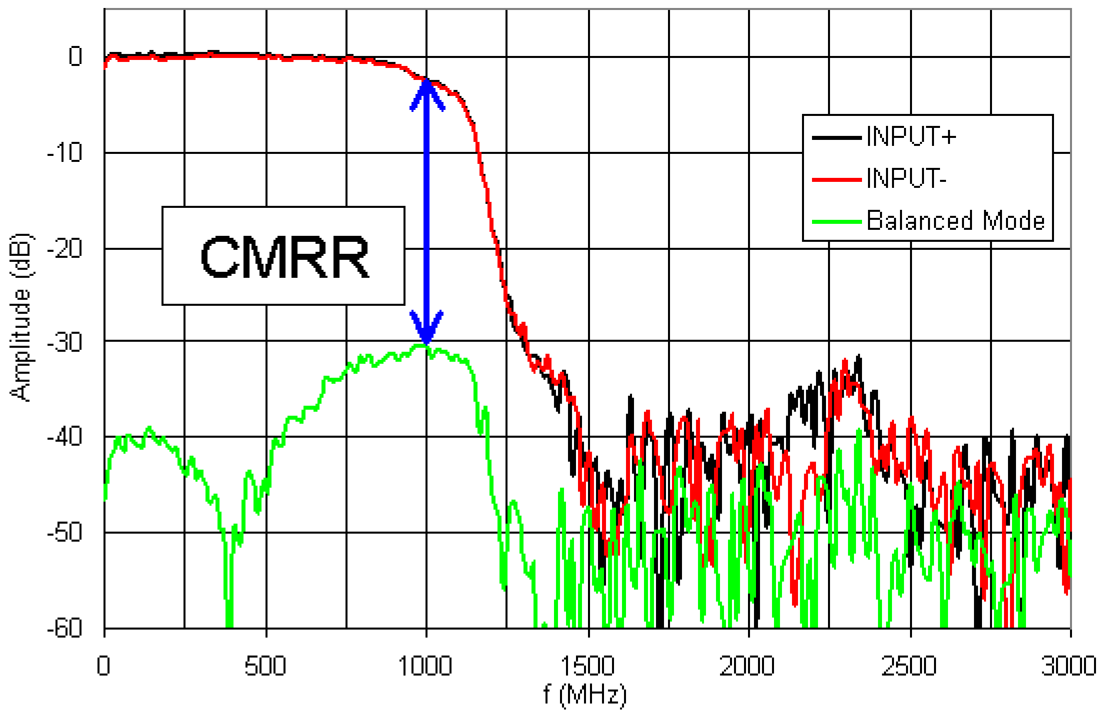


PDB480C-AC - Typical RF-OUTPUT Spectral Noise

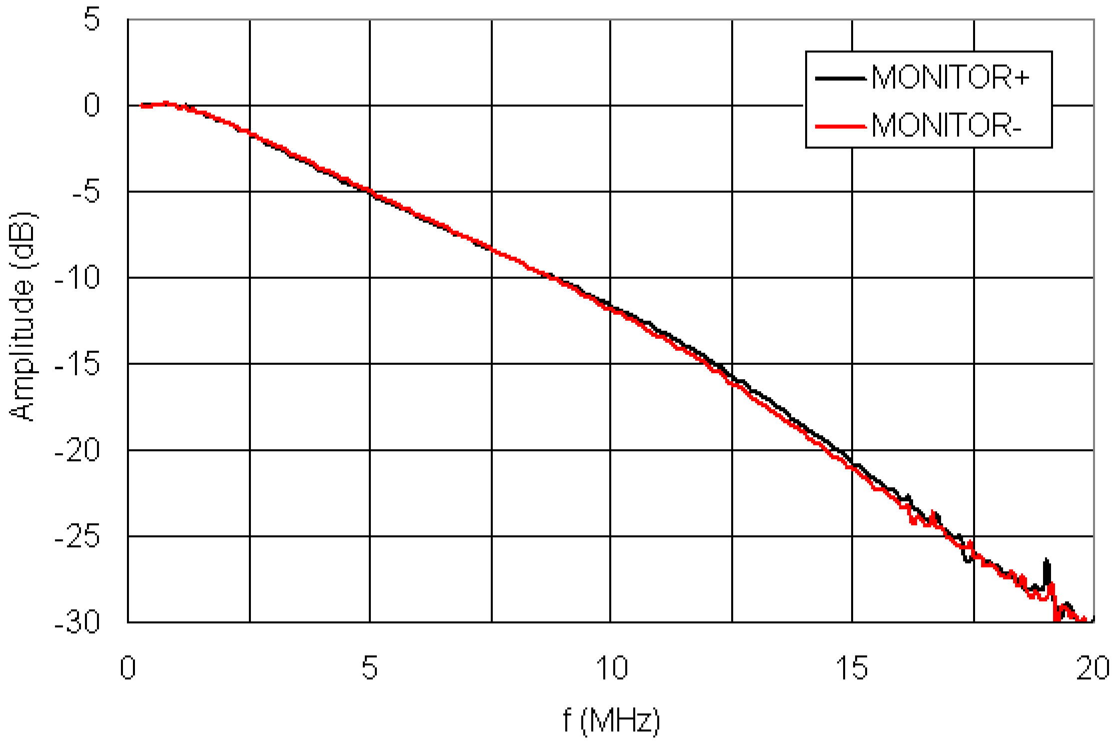
5.1.2 Individual Diagrams PDB481C-AC



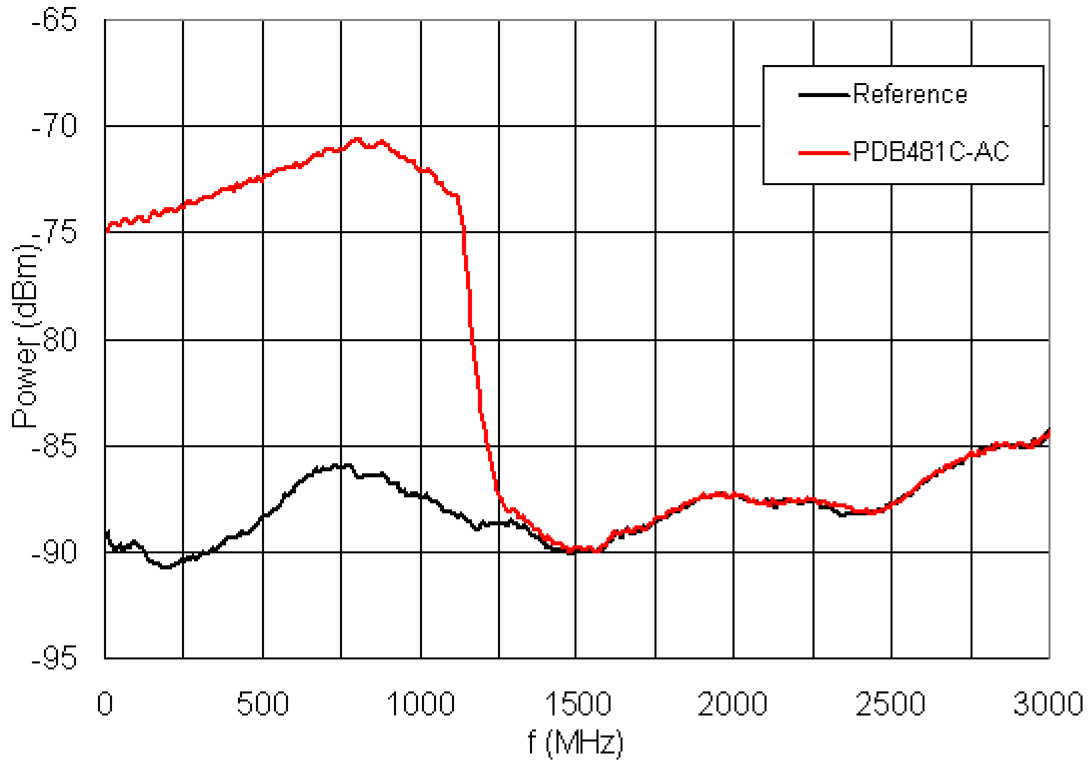
PDB481C-AC - Typical Detector Responsivity



PDB481C-AC - Typical RF OUTPUT Frequency Response

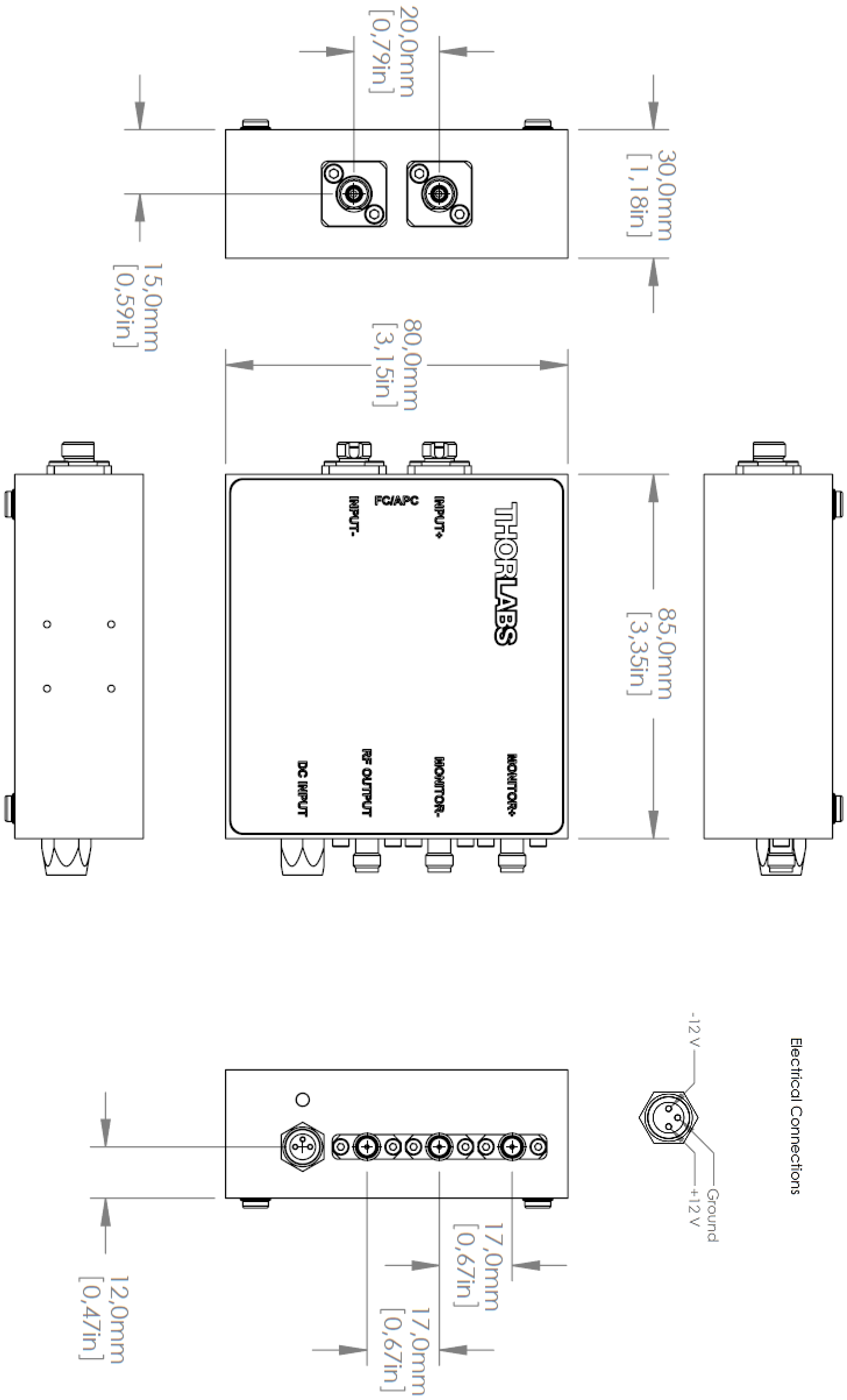


PDB481C-AC - Typical MONITOR OUTPUT Frequency Response



PDB481C-AC - Typical RF-OUTPUT Spectral Noise

5.2 Dimensions



PDB48xC-AC Mechanical Drawing

5.3 Certifications and Compliances

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We Thorlabs GmbH

Of Hans-Boeckler-Str. 6, 85221 Dachau/München, Deutschland

in accordance with the following Directive(s):

2006/95/EC	Low Voltage Directive (LVD)
2004/108/EC	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***PDB4 Series***

Equipment: ***Balanced Receiver***

is in conformity with the applicable requirements of the following documents:

EN61010 -1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010
EN61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed: D. Jennrich *On:* 19 September 2014

Name: Dorothee Jennrich

Position: General Manager

EDC - PDB4 Series -2014-09-19

CE 14

5.4 Warranty

Thorlabs warrants material and production of the PDB48xC-AC for a period of 24 months starting with the date of shipment. During this warranty period Thorlabs 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. The customer will carry the shipping costs to Thorlabs, in case of warranty repairs Thorlabs will carry the shipping costs back to the customer.

If no warranty repair is applicable the customer also has to carry the costs for back shipment.

In case of shipment from outside EU duties, taxes etc. which should arise have to be carried by the customer.

Thorlabs warrants the hard- and software determined by Thorlabs for this unit to operate fault-free provided that they are handled according to our requirements. However, Thorlabs does not warrant a fault free and uninterrupted operation of the unit, of the software or firmware for special applications nor this instruction manual to be error free. Thorlabs 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 stated by us or unauthorized maintenance.

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

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

5.5 Copyright and Exclusion of Reliability

Thorlabs has taken every possible care in preparing this Operation Manual. We however assume no liability for the content, completeness or quality of the information contained therein. The content of this manual is regularly updated and adapted to reflect the current status of the software. We furthermore do not guarantee that this product will function without errors, even if the stated specifications are adhered to.

Under no circumstances can we guarantee that a particular objective can be achieved with the purchase of this product.

Insofar as permitted under statutory regulations, we assume no liability for direct damage, indirect damage or damages suffered by third parties resulting from the purchase of this product. In no event shall any liability exceed the purchase price of the product.

Please note that the content of this User Manual is neither part of any previous or existing agreement, promise, representation or legal relationship, nor an alteration or amendment thereof. All obligations of *Thorlabs* result from the respective contract of sale, which also includes the complete and exclusively applicable warranty regulations. These contractual warranty regulations are neither extended nor limited by the information contained in this User Manual. Should you require further information on this product, or encounter specific problems that are not discussed in sufficient detail in the User Manual, please contact your local *Thorlabs* dealer or system installer.

All rights reserved. This manual may not be reproduced, transmitted or translated to another language, either as a whole or in parts, without the prior written permission of *Thorlabs.*

5.6 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 figure below)
- 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.).

Waste treatment on your own responsibility

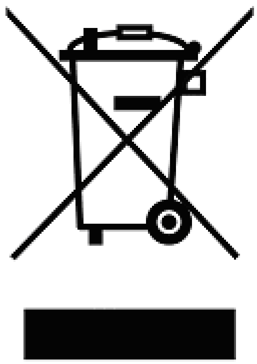
If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

WEEE Number (Germany) : DE97581288

Ecological background

It is well known that waste treatment 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-life products will thereby avoid negative impacts on the environment.



Crossed out "Wheelie Bin" symbol

5.7 Thorlabs Worldwide Contacts

USA, Canada, and South America

Thorlabs, Inc.
56 Sparta Avenue
Newton, NJ 07860
USA
Tel: 973-579-7227
Fax: 973-300-3600
www.thorlabs.com
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