THORLABS

PBM42

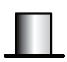
Photodiode Bias Module
For Mounted Photodiodes

User Guide

Table of Contents

Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal
	Protective Conductor Terminal
	Frame or chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control
	Out Position of a Bi-Stable Push Control
	Caution, Risk of Electric Shock
	Caution, Hot Surface
	Caution, Risk of Danger
	Warning, Laser Radiation
	Caution, Spinning Blades May Cause Harm

Chapter 2 Safety

CAUTION

Using the PBM42 to forward bias the photodiode can damage the photodiode.

Chapter 3 Description

The PBM42 Photodiode Bias Module is designed to be used with the Thorlabs SM05PDxx and SM1PDxx Mounted Photodiodes. The output uses a female SMA connector to minimize size. The mounted photodiodes are connected to the input female BNC connector with a cable or an adapter. The maximum bandwidth is 350 MHz. The photodiode is DC coupled to the output. Bias voltage is supplied through a 2.5 mm sub-mini phono jack. A 2.5 mm phono plug and cable is provided for the user external bias supply. Bias polarity determined by external power supply.

A low noise power supply is recommended for use with the PBM42.

Mounted photodiodes compatibility:

SM05PD7A	Mounted GaP Photodiode, 150-550 nm, Cathode Grounded.
SM05PD2A	Mounted Silicon Photodiode, 200-1100 nm, Cathode Grounded.
SM05PD1A	Large Area Mounted Silicon Photodiode, 350-1100 nm, Cathode Grounded.
SM05PD4A	Mounted InGaAs Photodiode, 800-1800 nm, Cathode Grounded.
SM05PD5A	Large Area Mounted InGaAs Photodiode, 800-1800 nm, Cathode Grounded.
SM05PD6A	Mounted Germanium Photodiode, 800-1800 nm, Cathode Grounded.
SM05PD1B	Large Area Mounted Silicon Photodiode, 350-1100 nm, Anode Grounded.
SM05PD2B	Mounted Silicon Photodiode, 200-1100 nm, Anode Grounded.
SM1PD2A	Mounted UV Enhanced Silicon Photodiode, 200-1100 nm, Cathode Grounded.
SM1PD1A	Large Area Mounted Silicon Photodiode, 400-1100 nm, Cathode Grounded
SM1PD5A	Mounted Germanium Photodiode, 800-1800 nm, Cathode Grounded.
SM1PD1B	Large Area Mounted Silicon Photodiode, 400-1100 nm, Anode Grounded.

Chapter 4 Setup

The photodiode bias module can be set up in many different ways using our extensive line of mounted photodiodes. However, the detector should always be mounted and secured for best operation and the photodiode **MUST** always be **REVERSED BIASED.** Step 1 in the setup instructions below outline how to mount the detector onto a post.

1. Unpack the Photodiode Bias Module. Install a Thorlabs TR-series ½" diameter post into the 8-32- or M4-tapped hole, located on the bottom of the module, and mount the post into a PH-series post holder.

2. Connect the mounted photodiode to the module. For a direct connection, Thorlabs offers the T3533 adapter. For connection via a cable, the 2249-C-xx is available.

3. Connect an SMA cable to the output end of the module. Depending on your application and voltage measurement device, select and install a terminating resistor. For best frequency performance, the module should be terminated with a 50 Ω terminator, such as our T4119. For flexibility in output voltage, a variable terminator (VT2) is available. Note the input impedance of your measurement device, since the device will act as a terminating resistor. A load resistor is not necessary when using current measurement devices.

4. Attach the power supply cable to an external power supply with the proper polarity and bias voltage for the photodiode. Reverse bias voltages for Thorlabs' mounted photodiodes are listed below. Insert the phono plug into the PBM42 module.

5. SM1PDxx and SM05PDxx maximum Reverse Bias voltage

SM1PD1A	Cathode Grounded	Reverse Bias Voltage = 25 volts max
SM1PD1B	Anode Grounded	Reverse Bias Voltage = 25 volts max
SM1PD2A	Cathode Grounded	Reverse Bias Voltage = 5 volts max
SM1PD5A	Cathode Grounded	Reverse Bias Voltage = 1 volt max
SM05PD1A	Cathode Grounded	Reverse Bias Voltage = 25 volts max
SM05PD2A	Cathode Grounded	Reverse Bias Voltage = 30 volts max
SM05PD4A	Cathode Grounded	Reverse Bias Voltage = 5 volts max
SM05PD5A	Cathode Grounded	Reverse Bias Voltage = 3 volts max
SM05PD6A	Cathode Grounded	Reverse Bias Voltage = 3 volts max
SM05PD7A	Cathode Grounded	Reverse Bias Voltage = 5 volts max
SM05PD1B	Anode Grounded	Reverse Bias Voltage = 20 volts max
SM05PD2B	Anode Grounded	Reverse Bias Voltage = 30 volts max

Note: **For Cathode grounded diodes, the tip of the phono plug must be positive. For Anode grounded diodes, the tip of the phono plug must be negative.**

6. Apply a light source to the detector.

Chapter 5 Operation

5.1. Theory of Operation

A junction photodiode is an intrinsic device, which behaves similarly to an ordinary signal diode, but it generates a photocurrent when light is absorbed in the depleted region of the junction semiconductor. A photodiode is a fast, linear device that exhibits high quantum efficiency based upon the application and used in a variety of different applications.

It is necessary to be able to determine correctly the level of the output current to expect and the responsivity based upon the incident light. Depicted in Figure 1 is a junction photodiode model with basic discrete components to help visualize the main characteristics and gain a better understanding of the operation of Thorlabs' photodiodes.

$$I_{OUT} = I_{DARK} + I_{PD}$$

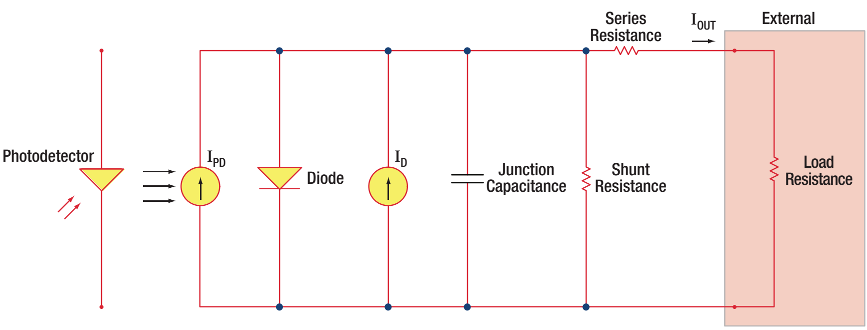


Figure 1 Photodiode Model

5.2. Responsivity

The definition of photodiode responsivity is the ratio of generated photocurrent (I_{PD}) to the incident light power (P) at a given wavelength:

$$R(\lambda) = \frac{I_{PD}}{P}$$

5.3. Modes of Operation

The photodiode can operate in one of two modes: photoconductive (reverse bias) or photovoltaic (zero-bias). Mode selection depends upon the applications speed requirements and the amount of tolerable dark current (leakage current).

5.3.1. Photoconductive

In photoconductive mode, a reverse external bias is applied, which is the basis for our mounted series detectors. The current measured through the circuit indicates illumination of the device; the measured output current is linearly proportional to the input optical power. Applying a reverse bias increases the width of the depletion junction producing an increased responsivity with a decrease in junction capacitance and produces a linear response. Operating under these conditions tends to produce a larger dark current, but this can be limited based upon the photodiode material. (Note: The mounted detectors **MUST BE Reverse Biased** and cannot be operated under a forward bias.)

Note
The mounted detectors are reverse biased and cannot be operated under forward bias conditions.

5.3.2. Photovoltaic

In photovoltaic mode, the photodiode is zero biased. The flow of current out of the device is restricted and a voltage builds up. This mode of operation exploits the photovoltaic effect, which is the basis for solar cells. When operating in photovoltaic mode the amount of dark current is at a minimum setting.

5.4. Dark Current

When we apply a bias voltage to a photodiode, it produces a leakage current called dark current. Photoconductive mode tends to generate a higher dark current that varies directly with temperature. It infers that, dark current can approximately double for every 10 °C increase in temperature, and shunt resistance can double for every 6 °C rise. Of course, applying a higher bias will decrease the junction capacitance but will increase the amount of dark current present.

The photodiode material and the size of the active area also affect the dark current. Silicon devices generally produce low dark current compared to germanium devices, which have high dark currents. The table on the next page lists several photodiode materials and their relative dark currents, speeds, sensitivity, and costs.

The table below gives some advantages to each common type of detector material.

Material	Dark Current	Speed	Sensitivity[1] (nm)	Cost
Silicon (Si)	Low	High	400 – 1000	Low
Germanium (Ge)	High	Low	900 – 1600	Low
Gallium Phosphide (GaP)	Low	High	150 – 550	Med
Indium Gallium Arsenide (InGaAs)	Low	High	800 – 1800	Med
Extended Range: Indium Gallium Arsenide (InGaAs)	High	High	1200 – 2600	High

5.5. Junction Capacitance

Junction capacitance (C_J) is an important property of a photodiode as this can have a profound impact on the bandwidth and the response of a photodiode. It reaffirms that larger diode areas encompass a greater junction volume with increased charge capacity. In a reverse bias application, the depletion width of the junction increases, thus effectively reducing the junction capacitance and increasing the response speed.

5.6. Bandwidth and Response

A load resistor will react with the photo detector junction capacitance to limit the bandwidth. For best frequency response, a 50 Ω terminator should be used in conjunction with a 50 Ω coaxial cable. The bandwidth (f_{BW}) and the rise time response (t_r) can be approximated using the junction capacitance and the load resistance (R_{LOAD}):

$$f_{BW} = \frac{1}{(2\pi\, R_{LOAD} \times C_j)}$$

$$t_r = \frac{0.35}{f_{BW}}$$

[1] *Approximate values, actual wavelength values will vary from unit to unit.*

5.7. Terminating Resistance

We use a load resistance to convert the generated photocurrent into a voltage (V_{OUT}) for viewing on an oscilloscope:

$$V_{OUT} = I_{OUT} \times R_{LOAD}$$

Depending on the type of the photodiode, load resistance can affect the response speed. For maximum bandwidth, we recommend using a 50 Ω coaxial cable with a 50 Ω terminating resistor at the opposite end of the cable. This will minimize ringing by matching the cable with its characteristic impedance. If bandwidth is not important, you may increase the amount of voltage for a given light level by increasing R_{LOAD}. In an unmatched termination, the length of the coaxial cable can have a profound impact on the response, thus is recommendable to keep the cable as short as possible.

5.8. Shunt Resistance

Shunt resistance represents the resistance of the zero-biased photodiode junction. An ideal photodiode will have an infinite shunt resistance, but actual values may range from the order of ten Ω to thousands of MΩ and is dependent on the photodiode material. For example, an InGaAs detector has a shunt resistance in the order of 10 MΩ, while a Ge detector is in the kΩ range. This can significantly affect the noise current on the photodiode. For most applications, however, the high resistance produces little effect and can be ignored.

5.9. Series Resistance

Series resistance models the resistance of the semiconductor material, and we ignore this low resistance. The series resistance arises from the contacts and the wire bonds of the photodiode; this mainly determines the linearity of the photodiode under zero bias conditions.

5.10. Damage Threshold

Exposure to an intense light source can easily damage a photodiode. One of the main characteristics of a damaged photodiode is the presence of increased dark current, along with burn spots on the detector active area. The damage threshold may vary from photodiode to photodiode, as this is generally dependent on material. Silicon devices tend to be more durable than InGaAs and can handle higher energy levels.

The formula below calculates the energy of each pulse, using the average power and the repetition rate. If the pulse width is given, the peak power can also be determined.

$$Pulse_{Energy}\ (J) = Average\ Power\ (W) * T_{pulse}\ (s)$$

$$Peak\ Power\ (W) = \frac{Pulse_{Energy}\ (J)}{Pulse\ Width\ (s)}$$

5.11. Bias Power Supply and Cable

Thorlabs delivers each PBM42 module with a 2.5 mm sub-mini phono plug with a three foot power cable for connection to the user supplied power supply. It is recommended to use a **well regulated, low noise** power supply for biasing the photodiodes. **For grounded cathode photodiodes, the tip of the power connector must be positive. For grounded anode photodiodes, the tip of the power connector must be negative.**

CAUTION

Forward biasing the photodiode can damage the photodiode.

Never apply a higher voltage than the maximum reverse bias rating of the photodiode. See Chapter 3, page 3 for a list of Thorlabs Mounted Photodiodes and bias voltages.

Chapter 6 Common Operating Circuits

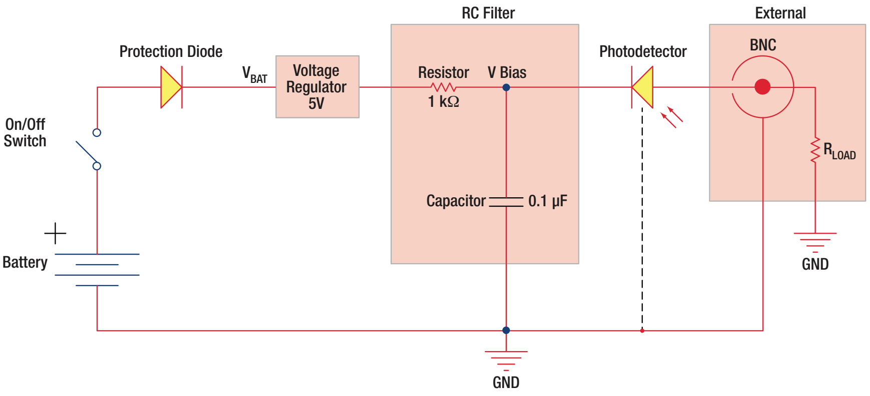


Figure 2 Basic DET Circuit

The DET Series Detectors are designed according the circuit depicted above. The detector is reverse biased to produce a linear response with applied input light. The generated photocurrent is based upon the incident light and wavelength and can be viewed on the oscilloscope by attaching a load resistance on the output. The function of the RC Filter is to filter any high frequency noise from the input supply, which may contribute to a noisy output.

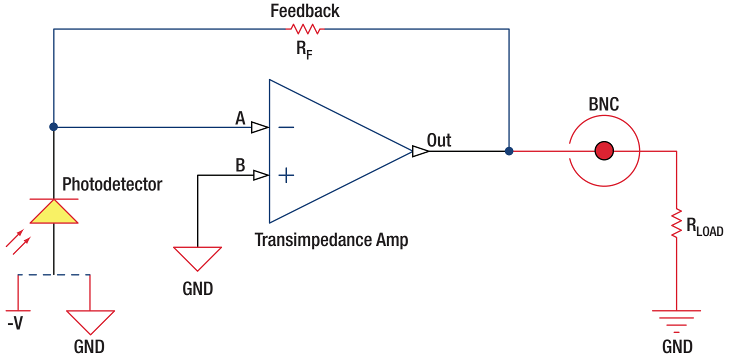


Figure 3 Amplified Detector

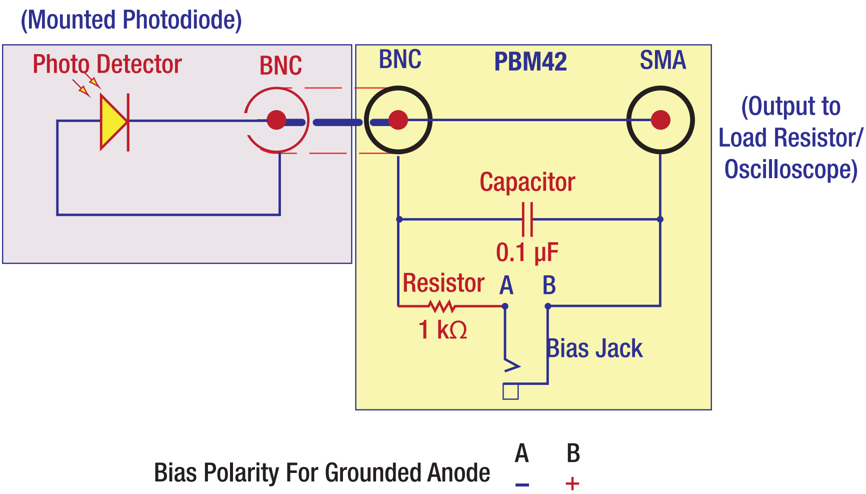
We can achieve high gain when using a photo detector with an amplifier. The user can choose whether to operate in Photovoltaic of Photoconductive modes. There are a few benefits of choosing this active circuit:

- Photovoltaic Mode: We maintain the circuit at zero volts across the photodiode, holding point A at the same potential as point B by the operational amplifier. This eliminates the possibility of dark current.
- Photoconductive mode: We reverse bias the photodiode; it improves the bandwidth while lowering the junction capacitance. The gain of the detector is dependent on the feedback element (R_F). The bandwidth of the detector can be calculated using the following:

$$f(-3dB) = \sqrt{\frac{GBP}{4\pi R_f \times C_D}},$$

Where GBP is the amplifier product gain-bandwidth and C_D is the sum of the junction capacitance, amplifier capacitance, and feedback capacitance.

Grounded Anode



Grounded Cathode

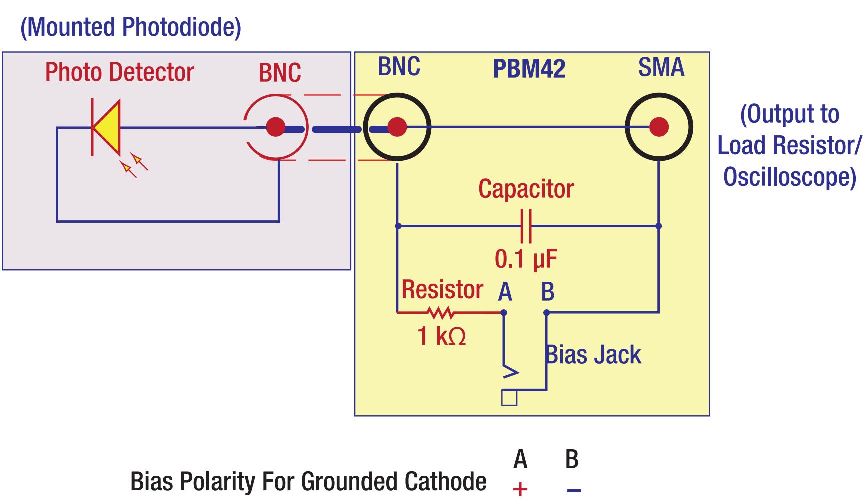


Figure 4 PBM42 Circuit Diagram

Chapter 7 Troubleshooting

Problem	Suggested Solutions
There is no signal response.	Verify that the Bias Supply is on and the diode is reversed biased at the proper voltage level. The bias voltage can be checked by measuring between the BNC shied on the photodiode to the SMA output shield. For grounded cathode the BNC shield will be positive with respect to the SMA. For grounded anode the BNC shield will be negative with respect to the SMA shield.
	Verify the proper terminating resistor is installed if using a Voltage measurement device.
	Verify that the optical signal wavelength is within the specified wavelength range.
	Verify that the optical signal is illuminating the detector active area.
	Connect the PBM42 to an oscilloscope without a terminating resistor installed. Most general purpose oscilloscopes will have a1 MΩ input impedance. Point the detector toward a fluorescent light and verify that a 60 Hz (50 Hz outside the US) signal appears on the scope. If so the device should be operating properly and the problem may be with the light source or alignment.
There is an AC signal present when the unit is turned off.	The detector has an AC path to ground even with the bias switch OFF. It is normal to see an output response to an AC signal with the bias in this state. However, because the detector is unbiased, operation in this mode is not recommended.
The output appears AC coupled with long rise times and the power switch ON.	This is usually an indication that the bias voltage is to low and needs to be changed.
Skewed Rise and Fall Times	Check to see if the bias voltage is too low. Make sure you are not saturating the detector as this can lead to permanent damage.

Chapter 8 Specifications

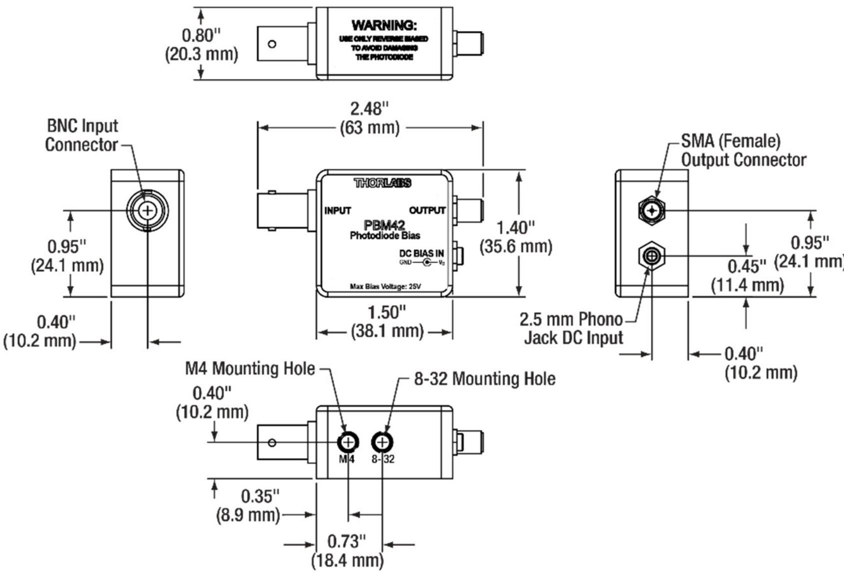
All measurements performed with a 50 Ω load unless stated otherwise.

Electrical Specifications		
Parameter	**Symbol**	**Value**
Detectors		Thorlabs Mounted Photodiodes
Wavelength Range[2]	λ	150 to 1800 nm
Cutoff Frequency[3]	f_{BW}	350 MHz (Typ.)
Bias Voltage	V_R	-25 to +25 V

General	
Input	Female BNC
Output	SMA (DC Coupled)
Package Size (Includes Connectors)	2.48" x 1.40" x 0.80" (63.0 mm x 35.6 mm x 20.3 mm)
Weight	38.2 g
Storage Temp	0 to 40 °C
Operating Temp	0 to 40 °C
Bias Supply Connector	2.5 mm Sub-Mini Phono Jack
Bias Supply Cable	2.5 mm Sub-Mini Phono Plug with 36" Cable

[2] *Wavelength range is determined by the photodiode.*
[3] *Cutoff Frequency is dependent on the photodiode.*

Chapter 9 Mechanical Drawing



Chapter 10 Regulatory

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 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- 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

Wheelie Bin Logo

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.

10.1.Waste Treatment is 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.

10.2.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 life products will thereby avoid negative impacts on the environment.

Chapter 11 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.

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