Model 1815-C Optical Power Meter

OPERATOR MANUAL

Newport

Newport®

EC DECLARATION OF CONFORMITY

Model 1815C

We declare that the accompanying product, identified with the "CE" mark, meets the intent of the Electromagnetic Compatability Directive, 89/336/EEC and Low Voltage Directive 73/23/EEC.

Compliance was demonstrated to the following specifications:

EN50081-1 EMISSIONS:
Radiated and conducted emissions per EN55011, Group 1, Class A

EN50082-1 IMMUNITY:
Electrostatic Discharge per IEC 1000-4-2, severity level 3
Radiated Emission Immunity per IEC 1000-4-3, severity level 2
Fast Burst Transients per IEC 1000-4-4, severity level 3
Surge Immunity per IEC 1000 4-5, severity level 3

IEC SAFETY:
Safety requirements for electrical equipment specified in IEC 1010-1.

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Safety Symbols and Terms

The following safety terms are used in this manual:

The **Warning** heading in this manual explains dangers that could result in personal injury or death.

The **Caution** heading in this manual explains hazards that could damage the instrument.

In addition, a **Notes** heading gives information to the user that may be beneficial in the use of this instrument.

General Warnings and Cautions

The following general warnings and cautions are applicable to this instrument:

Warning

The American National Safety Institute (ANSI) states that a shock hazard exists when probes or sensors are exposed to voltage levels greater then 42VDC or 42V peak AC. Do not exceed 42V RMS between any portion of the Model 1815-C (or any attached detector or probe) and earth ground or a shock hazard will result.

Caution

There are no user serviceable parts inside the Model 1815-C. Work performed by persons not authorized by Newport may void the warranty. For instructions on obtaining warranty repair or service please refer to Section 5 of this manual.

Note

The Model 1815-C is a battery powered device with no internal voltages exceeding 9V.

Definitions

A	amp
ADC	analog-to-digital converter
BAT	battery option
BNC	standard coaxial connector type
°C	degrees Centigrade
DC	direct current
°F	degrees Fahrenheit
Hz	hertz (cycles per second)
I-V	current-to-voltage converter
kHz	kilohertz
kΩ	kiloOhm
mA	milliamp
mV	millivolt
nA	nanoamp
nF	nanofarad
nm	nanometer
RH	relative humidity
rms	root-mean-square
S/N	serial number
μA	microamp
μs	microsecond
V	volt
W	watt

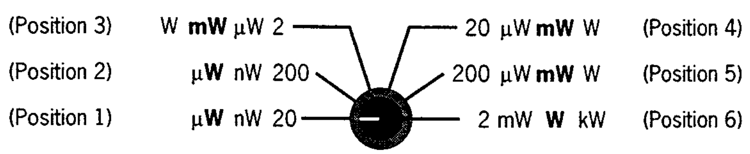
Specifications

Physical Specifications

Dimensions:	3.25 × 6.0 × 6.25 in (83 × 152 × 159 mm)
Weight:	1.5 lb (0.7 kg)
Enclosure:	Plastic, ABS
Connectors:	Signal Input BNC; Signal Output BNC
Power:	6x 1.5 V AA batteries (alkaline)
Battery Life:	130–180 hrs. (alkaline)
Display:	3.5 Digit, LCD
Sample Rate:	2.5 Hz
Range Switch:	6 positions, one per decade of gain
Operating Environment:	<70% RH Noncondensing 18°C – 28°C (65°F – 82°F)
Storage Environment:	<90% RH Noncondensing
Compatible Detectors:	Newport Low-Power Detectors — except 818-F-SL, 818-F-IR Newport High-Power Detectors

Electrical Specifications:

Range Knob Positions



Current Amplification (Low-Power Detectors)

Range Switch Position	1	2	3	4	5	6
Low-Power Full Scale	20.00 nW	200.0 nW	2.000 µW	20.00 µW	200.0 µW	2.000 mW
Low-Power Full Scale (with Attenuator)	20.00 µW	200.0 µW	2.000 mW	20.00 mW	200.0 mW	2.000 W
Full Scale Current:[1]	20.00 nA	200.0 nA	2.000 µA	20.00 µA	200.0 µA	2.000 mA
Display Accuracy						
Maximum Error	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
Expected (rms) Error	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Display Resolution	10 pA	100 pA	1 nA	10 nA	100 nA	1 µA
Display Noise Floor[2]	<10 pA	<100 pA	<1 nA	<10 nA	<100 nA	<1 µA
Signal Gain[1]	10^8	10^7	10^6	10^5	10^4	10^3
Absolute Maximum Input Rating:	Current	5 mA				
	Voltage	–6V to +3V				
Input Impedance	0 ohm					

[1] CAL Factor = 1.00E+0

[2] Display Noise Floor scales with the calibration factor in the following way:
Display Noise Floor = (specified noise floor) × (calibration factor mantissa)

Voltage Amplification (High-Power Detectors)

Range Switch Position			3	4	5	6
High Power Full Scale			2.000 W	20.00 W	200.0 W	2.000 kW
Full Scale Voltage:[1]			2.000 mV	20.00 mV	200.0 mV	2.000 V[2]
Display Accuracy						
Maximum Error			1.9%	1.9%	1.9%	1.9%
Expected (rms) Error			0.4%	0.4%	0.4%	0.4%
Display Resolution			1 µV	10 µV	100 µV	1 mV
Display Noise Floor[3]						
Accelerator Off			<1 µV	<10 µV	<100 µV	<1 mV
Accelerator On[4]			<40 µV	<40 µV	<400 µV	<1 mV
Signal Gain[1]			10^3	10^2	10^1	10^0
Absolute Maximum Input Rating:	Voltage	–6V to +3V				
Input Impedance	1M ohm					

[1] CAL Factor = 1.00E+0

[2] The maximum measurable input voltage allowed by the 1815-C is 300 mV.

[3] Display Noise Floor scales with the calibration factor in the following way:
Display Noise Floor = (specified noise floor) × (calibration factor mantissa)

[4] ACCEL ADJ fully clockwise (worst case)

Analog Output

Range Switch Position	1	2	3	4	5	6
Analog Output Full Scale:[1]	2.000 V	2.000 V	2.000 V	2.000 V	2.000 V	2.000 V
Accuracy (relative to display)	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Bandwidth[2]						
Current Amplification	10 Hz	10 Hz	4 kHz	9 kHz	4 kHz	9 kHz
Voltage Amplification			15 Hz	15 Hz	15 Hz	15 Hz
Noise Floor[3,4,5]						
Current Amplification						
0.1 Hz – 3 Hz	<1 mV_{p-p}	<0.5 mV_{p-p}	<0.5 mV_{p-p}	<0.5 mV_{p-p}	<0.5 mV_{p-p}	<0.5 mV_{p-p}
0.1 Hz – 100 Hz	<4	<0.5	<1.5	<0.5	<1.5	<0.5
0.1 Hz – 30 kHz	<6	<1	<4	<1	<4	<1
Voltage Amplification						
Accelerator Off						
0.1 Hz – 3 Hz			<3 mV_{p-p}	<0.5 mV_{p-p}	<0.5 mV_{p-p}	<0.5 mV_{p-p}
0.1 Hz – 100 Hz			<25	<2	<1.5	<0.5
0.1 Hz – 30 kHz			<30	<4	<4	<1
Accelerator On[6]						
0.1 Hz – 3 Hz			<80 mV_{p-p}	<8 mV_{p-p}	<8 mV_{p-p}	<1 mV_{p-p}
0.1 Hz – 100 Hz			<120	<10	<10	<1
0.1 Hz – 30 kHz			<120	<10	<10	<2
Output Impedance:	1 k ohm					

1 CAL Factor = 1.00E+0

2 Bandwidth specifications for the current amplification mode were measured with an 818-SL detector.

3 Analog Output Noise Floor scales with the calibration factor in the following way: Analog Output Noise Floor = (specified noise floor) × (calibration factor mantissa)

4 The specified values are representative of meter/detector system noise.

5 If the noise floor is greater than specified, see Section 3.3.2 (Quantum Detector Temperature Effects)

6 ACCEL ADJ fully clockwise (worst case)

Detector Responsivity Limits†:

Detector in Use	Allowed Responsivities	Allowed Calibration Factors
Low-Power	5.26E–2 to 1.11E+1 A/W	0.90E–1 to 19.00E+0 W/A
Low-Power with Attentuator	5.26E–5 to 1.11E–2 A/W	0.90E+2 to 19.00E+3 W/A
High-Power		
Gain Position 3	5.26E–5 to 2.00E–3 V/W	5.00E+2 to 19.00E+3 W/V[1]
Gain Position 4	5.26E–5 to 2.00E–3 V/W	5.00E+2 to 19.00E+3 W/V[1]
Gain Position 5	5.26E–5 to 1.54E–3 V/W	6.50E+2 to 19.00E+3 W/V[1]
Gain Position 6	5.26E–5 to 1.54E–4 V/W	6.50E+3 to 19.00E+3 W/V[1,2]

1 If a calibration factor less than those specified is used, the internal electronics will saturate before full scale readings are reached. For Newport detectors, electronic saturation only occurs if the detectors are used well beyond their damage thresholds.

2 300 mV is the maximum input voltage allowed before the internal electronics saturate.

† These limits allow the use of compatible Newport detectors over their calibrated operating ranges.

Zeroing Offset Dynamic Range: Covers the 4–5 highest gain decades. Actual range varies with parameter settings.

Zero Drift: With CAL Factor = 1.00E+0 and range switch set to 20nW in current mode, the display reads <1% of Full Scale over 12 hours at ± 2°F.

Section 1

General Information

1.1 System Overview

The Model 1815-C is an accurate low cost optical power meter that provides optical measurement capability from nanowatts to kilowatts. Front panel Range and ZERO functions facilitate use while a wavelength compensation CAL feature insures that NIST/NPL traceable measurements can be performed. Compatible with Newport's Low-Power and High-Power detector families, the Model 1815-C covers the majority of optical power measurement needs. The Model 1815-C Optical Power Meter and its accessories are presented in Figure 1. Section 1.5 in this manual presents a detailed description of available accessories and options.

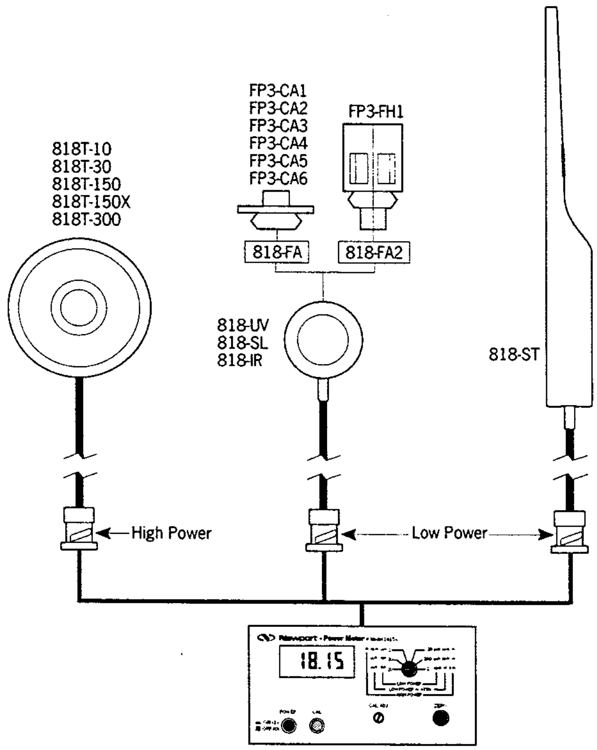


Figure 1 — Model 1815-C Controller and Accessories

1.2 Scope of this manual

Please carefully read this instruction manual before using the Model 1815-C. Be especially careful to observe the warnings and cautions throughout this manual (see General Warnings and Cautions). If any operating instructions are **not** clear, contact Newport Corporation.

This instruction manual contains the necessary information for operation and maintenance of the Newport Model 1815-C as well as information for trouble-shooting and obtaining service if necessary. This information is divided into the following sections:

- Section 1 provides General Information about the Model 1815-C.
- Section 2 provides System Operation procedures.

- Section 3 provides information about the Principles of Operation of the Model 1815-C.
- Section 4 provides for Test, Maintenance and Adjustment of the Model 1815-C.
- Section 5 provides instructions for obtaining Factory Service.

1.3 Unpacking and Inspection

All Model 1815-C Optical Power Meters are carefully assembled, tested, and inspected before shipment. Upon receiving this instrument, check for any obvious signs of physical damage that might have occurred during shipment. Report any such damage to the shipping agent immediately. Retain the original packing materials in case reshipment becomes necessary.

1.4 Preparation for Use

The Model 1815-C Optical Power Meter should have some operations performed before measurements are made. These include:

- Connection and calibration of the detector (Section 2.4.3 and 2.4.4)

1.5 Optional Accessories and Services

The following table describes the accessories and services available for use with the Model 1815-C Optical Power Meter. Refer to Figure 1 for where each accessory fits within the Model 1815-C Optical Power Meter family tree. For more information, please refer to the Newport Catalog.

Table 1 — Model 1815-C Compatible Detectors

Accessory	Description
Low-Power Detectors	
818-UV	0.25 to 1.1 µm, silicon, cylindrical with detachable OD3 attenuator
818-SL	0.4 to 1.1 µm, silicon, cylindrical with detachable OD3 attenuator
818-IR	0.78 to 1.8 µm, germanium, cylindrical with detachable OD3 attenuator
818-ST	0.4 to 1.1 µm, silicon, wand detector with integral insertable OD3 attenuator
High-Power Detectors	
818T-10	10 W flat spectral response air cooled disk thermopile
818T-30	30 W flat spectral response air cooled disk thermopile
818T-150	150 W flat spectral response air cooled disk thermopile
818T-150X	150 W flat spectral response air cooled eximer optimized disk thermopile
818T-300	300 W flat spectral response water cooled disk thermopile

Section 2

System Operation

2.1 Introduction

This section contains the information needed to prepare and operate the Model 1815-C Optical Power Meter. Operation consists of using the Model 1815-C to perform basic optical power measurements using one of Newport's compatible detectors.

2.2 Front and Rear Panels

Operating controls and settings for the Model 1815-C are found on both the front and rear panels. For general operation, only the front panel controls are used. The rear panel controls and settings are used for meter/detector setup. The front and rear panels of the Model 1815-C are shown in Figures 2 and 3 respectively. The following table gives a short description of each Model 1815-C control:

Table 2 — Model 1815-C Controls

Control	Description	Comment
POWER	Push Button	Turns the Model 1815-C on and off
CAL	Push Button	Causes the meters CAL value to be displayed.
CAL ADJ	10 Turn Trim Pot	Sets the mantissa of the Calibration Factor.
ZERO	10 Turn Knob	Zeros the display. Used to eliminate ambient signals.
Range	6 Position Knob	Adjusts the meter's signal gain.
ACCEL ADJ	25 Turn Trim Pot	Sets the thermopile acceleration time constant.
SETUP	4 Switch DIP Bank	Configures the meter to the detector in use.

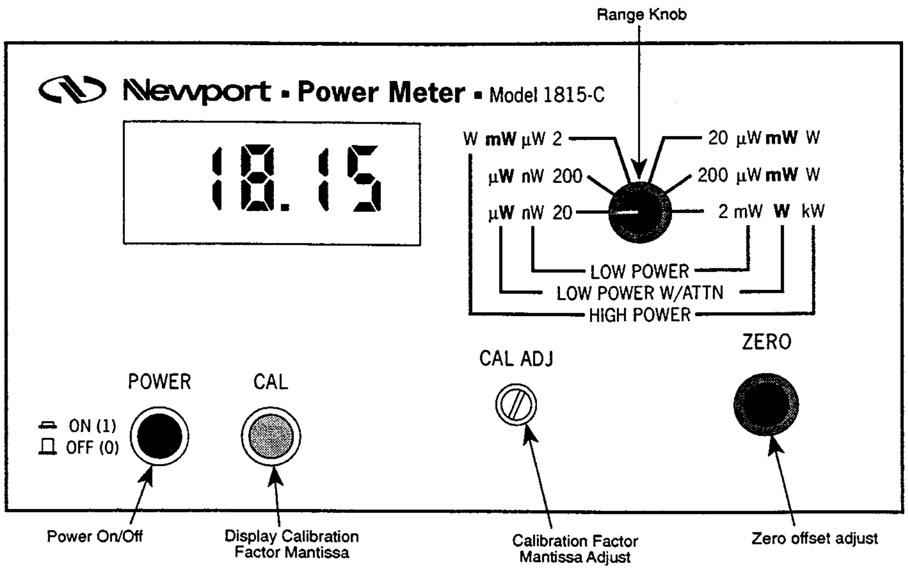


Figure 2—Model 1815-C Front Panel and Controls

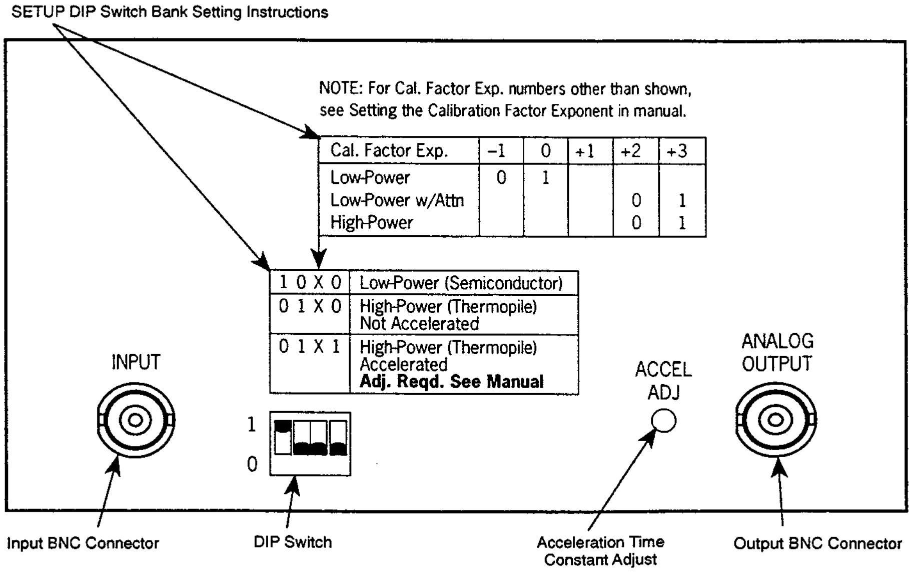


Figure 3—Model 1815-C Rear Panel and Controls

2.2.1 Range Knob

The Range knob is shown in Figure 4. This knob adjusts the signal gain of the Model 1815-C. The units arrayed around the knob reflect the units of measurement when using a particular type of Newport detector. As an example, if a measurement with a Low-Power detector with its attenuator was being made, then the proper units would be read from the middle (blue) column of units found on either side of the knob.

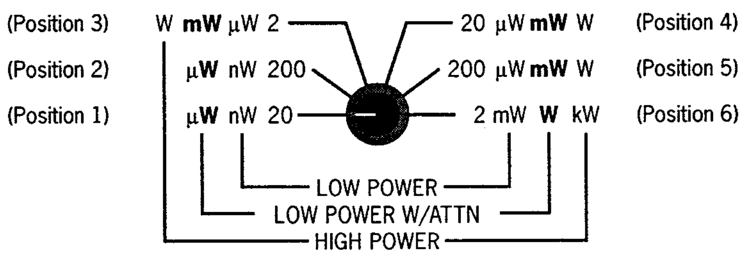


Figure 4 — Model 1815-C Range Knob

2.2.2 ZERO Knob

The ZERO knob adjusts the display and analog output values up or down. It is used to zero the display to remove the effects of low level ambient signals before making a measurement. The ZERO function can offset signals over a 5 decade range.

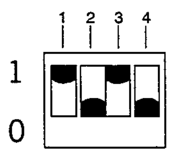
NOTE

Turn the ZERO knob clockwise (counter clockwise) to reduce (increase) the offsetting signal generated by the ZERO circuit.

2.2.3 SETUP DIP Switch Bank

The SETUP DIP switch bank configures the meter to the type of Newport detector the meter will be used with. The following table identifies the function each SETUP switch position performs:

Table 3 — SETUP DIP Switch Functions

SETUP Switch	Switch Position	Description
	1 & 2	Selects for Low-Power (semiconductor) detector (1,0) or High-Power (thermopile) detector (0,1).
	3	Sets the calibration factor exponent. See Section 2.4.4
	4	Selects Accelerated (1) or Not Accelerated (0) response. See Section 2.4.5

2.3 Getting Started

Please carefully read this instruction manual before using the Model 1815-C Optical Power Meter. If any operating instructions are **not** clear, contact Newport Corporation.

2.4 Using the System

The Model 1815-C Optical Power Meter relies on the user to properly install the calibration factor describing the detector at the measurement wavelength in use. In order to assure that accurately calibrated measurements are obtained, please carefully read and follow the instructions regarding Detector Calibration Factor and its entry. See Sections 2.4.4, 2.4.4.1 and 2.4.4.2.

2.4.1 Battery Installation/Replacement

The Model 1815-C uses a 3.5 digit announciated LCD display. The display's BAT announciator lights when the battery voltage has dropped to 7 volts and indicates that new batteries are needed. The Model 1815-C uses six 1.5V AA batteries. To replace these batteries use the following procedure:

1. Turn the Model 1815-C off and open the case by removing the two screws on the bottom of the meter.
2. Unfasten the velcro straps, and remove the batteries.
3. Insert six new 1.5V AA batteries (Alkaline) making sure to orient the polarity of the batteries as indicated by the battery holders.
4. Secure the velcro across batteries.
5. Close and resecure the case with the two screws.

2.4.2 Power Up

Turn on the Model 1815-C by depressing the POWER switch located on the front of the meter. The digital display should light indicating that the meter is operating. If the BAT announciator is lit, replace the batteries. See Section 2.4.1.

2.4.3 Detector Connection and Setup

Connect the detector to the INPUT BNC found on the rear of the Model 1815-C. You may connect or disconnect any Newport Low-Power, or High-Power detector at any time (even when the meter is on) without damage.

Adjust the SETUP switch bank to reflect the type of Newport detector that the Model 1815-C is being used with. If you are not using a Newport detector, follow the table below when setting up the Model 1815-C. This table is reproduced on the rear panel of the Model 1815-C, see Figure 3.

Table 4 — SETUP DIP Switch Settings

Detector Type	Responsivity Units	SETUP Switch Position 1	2	3	4
Low-Power (Semiconductor)	A/W	1	0	X†	0
High-Power (Thermopile) Not Accelerated	V/W	0	1	X†	0
High-Power (Thermopile) Accelerated	V/W	0	1	X†	1

† See Section 2.4.4.2 to determine the proper setting for switch position 3.

2.4.4 Setting the Detector Calibration Factor

The calibration factor tells the Model 1815-C how to account for a detector's responsivity at the measurement wavelength. Each Newport detector arrives with calibration information. The information will reflect detector responsivities and calibration factors. A calibration factor is calculated from a responsivity by simply taking the inverse of the responsivity and expressing it in scientific notation, i.e. d.ddE±d.

Example 1: Responsivity R = 0.568 A/W thus the Calibration Factor = 1.76 E+0 W/A

Example 2: Responsivity R = 0.346 mV/W thus the Calibration Factor = 2.89 E+3 W/V

Note

Be sure to re-express the responsivity value in units of A/W or V/W before calculating the inverse. See Example 2 above.

2.4.4.1 Setting the Calibration Factor Mantissa

The mantissa of the calibration factor is the d.dd of the full calibration factor value d.ddE±d. The mantissa is the most frequent calibration adjustment made when making measurements at various wavelengths. To set the mantissa, use the following procedure:

1. Press the front panel CAL button into its depressed position.
2. Adjust the front panel CAL ADJ until the display matches the calibration factor mantissa.

   Example: If the Calibration Factor = 2.89 E+3, then the display should indicate 2.89.
3. Release the CAL button from its depressed position.

NOTE

Set the calibration factor mantissa with the Accelerator circuit turned off. (SETUP DIP switch position 4)

2.4.4.2 Setting the Calibration Factor Exponent

The calibration factor exponent is the ±d of the full calibration factor value d.ddE±d discussed in Section 2.4.4. The exponent rarely needs to be set more than once when using the Model 1815-C with a particular detector. However it is still wise to check that the exponent does not need resetting when making measurements at multiple wavelengths. To set the exponent (SETUP switch position 3, see Section 2.2.3), use the following lookup table:

Table 5 — Calibration Factor Exponent; SETUP DIP Position 3

Calibration Factor Exponent	–2	–1	+0	+1	+2	+3	+4
Low-Power	0†	0	1	1‡	NA	NA	NA
Low-Power with Attenuator	NA	NA	NA	0†	0	1	1‡
High-Power	NA	NA	NA	0†	0	1	1‡

† Divide the mantissa by 10 and re-enter. Example: 9.00E–2 becomes 0.90E–1. Now 0.90 is the mantissa and –1 is the exponent.

‡ Multiply the mantissa by 10 and re-enter. Example 1.50E+4 becomes 15.00E+3. Now 15.00 is the mantissa and +3 is the exponent.

2.4.5 Detector Acceleration Time Constant

NOTE

Accelerator circuit will increase the noise floor level.

The Model 1815-C uses an acceleration circuit to electronically shorten the risetime of Newport's High-Power disk thermopile detectors. This is done when SETUP switch position 4 is set to "1". A back panel potentiometer, ACCEL ADJ, is used to adjust the time constant of the acceleration circuit to match the time constant of the detector. Since most of Newport's High-Power detectors have approximately a 1 second time constant, the ACCEL ADJ potentiometer is adjusted at the factory for this value. However, because the actual time constant is not exactly 1 second for all the smaller thermopiles, it may be required to optimize the acceleration.

You can set or fine tune the ACCEL ADJ to your particular detector. This is especially useful if you are monitoring the processed analog output on an oscilloscope or other time based or data logging instrument. This adjustment is required if you are using a High-Power detector that does not have a 1 sec. time constant. When the ACCEL ADJ setting does not match the actual time constant of the attached detector, you will see some overshoot or undershoot on the processed analog output signal. To fine tune the ACCEL ADJ potentiometer use the following procedure:

1. Set the SETUP DIP switch positions 1, 2, 3 and 4 to "0, 1, X, 1". Connect your High-Power detector and monitor the analog output on an oscilloscope.
2. Introduce a step function of optical power to the High-Power detector. You should observe a signal trace similar to Figure 5.
3. Adjust the ACCEL ADJ potentiometer until the overshoot or undershoot of the analog output signal is eliminated.

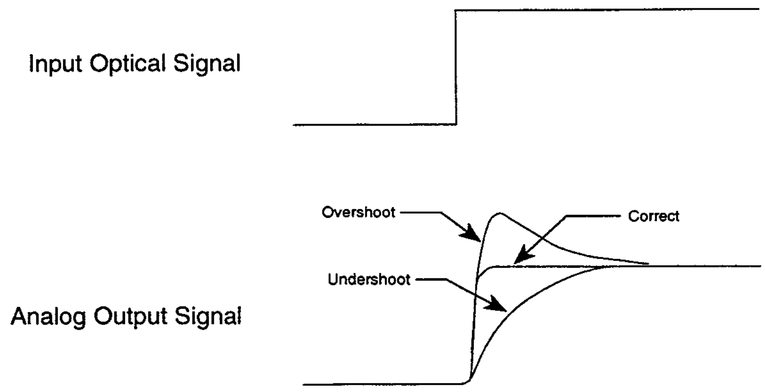


Figure 5—Detector Time Constant Acceleration Adjustment

Note

If you are operating the Model 1815-C with a High-Power detector and with the signal acceleration turned off, then no adjustment to the ACCEL ADJ is required.

Note

Acceleration can only be used with High-Power (thermopile) detectors. If acceleration is used with other detectors, erroneous readings can result.

2.4.6 Analog Output

The Model 1815-C provides a 0 to 2 volt BNC analog output for signal monitoring. The signal reflects actual power measured by being equal to the digital display value. Thus, if the digital display indicates 1.560, then the analog output voltage will be 1.560 volts.

Section 3
Principles of Operation

3.1 Introduction

The Model 1815-C is an optical power meter whose electronics can adapt to the signals from both semiconductor and themopile detectors. This versatility is required to handle the various signals that Newport's **Low-Power**, and **High-Power** detector families generate. These detector families are based on semiconductor and disk thermopile detectors respectively.

A block diagram of signal flow through the Model 1815-C is shown in Figure 6. The actual flow through the diagram depends upon the SETUP switch settings.

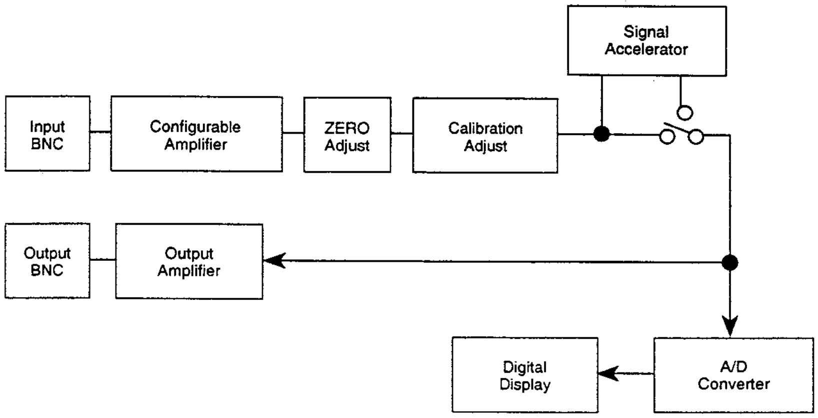


Figure 6 — Simplified Model 1815-C Functional Block Diagram

3.2 Functional Description

The Model 1815-C Optical Power Meter is a configurable current or voltage measuring instrument optimized for use with semiconductor photodiodes (current measurement) or disk thermopiles (voltage measurement).

Detector signals are introduced to the Model 1815-C by way of a BNC input connector. A bank of DIP switches found on the back of the Model 1815-C configures the amplifier as either a transimpedance current amplifier or as a 1 MΩ input impedance voltage amplifier. The amplified signal is then further processed via a ZERO offset adjust, a Calibration Factor compensation (adjustable signal attenuator) stage, and if appropriate a signal accelerator circuit. The resulting signal is then sent to the A-D converter and displayed.

3.3 Measurement Considerations

This section describes detector and attenuator characteristics, optical and electrical considerations, and environmental influences on optical measurements. In general, the accuracy of measurement with the Model 1815-C is limited by the calibration accuracy of the detector calibration. Making accurate measurements of optical power is however, also dependent upon properly setting up the Model 1815-C, controlling temperature and illumination conditions and understanding the factors that affect power measurement.

3.3.1 Detector Calibration and Accuracy

Newport Corporation calibrates its detectors using secondary standards directly traceable to the United States National Instiitute of Science and Technology (NIST) or to Great Britain's National Physical Laboratory, (NPL). The details and accuracy of the calibration procedure vary with each detector model but a detailed description of the calibration results is supplied with each individually calibrated detector.

In general, detector calibration accuracy ranges from 2% to 5% in absolute terms and varies with wavelength. Each detector will have some variation in the response over different sections of its surface. Therefore, for the most reproducible measurements, light should illuminate the detector as uniformly as possible over 80% of the detector's active area.

Caution

Avoid focusing a light source onto the detector surface. Inaccurate readings and possible detector damage may result. Consult your detector manual for information on detector saturation or damage thresholds.

NIST traceability requires that detectors be recalibrated on one year intervals. As individual detector responses change with time, especially in the ultraviolet, recalibration is necessary to assure confidence in the accuracy of the measurement. For the most reproducible measurements, the same detector should always be used for measurements which are to be directly compared.

3.3.2 Quantum Detector Temperature Effects

Semiconductor based photodiode detector characteristics (Newport Corporation **Low-Power** detectors) are significantly affected by temperature. At longer wavelengths, these quantum detectors typically lose sensitivity with increasing temperature. However the detector dark current increases exponentially with temperature. For silicon detectors, dark current is generally on the order of a few picoamps at room temperatures. With uncooled germanium detectors, however, this dark current is on the order of a nanoamp, or typically 1,000 to 10,000 times greater than silicon. These dark currents can be zeroed at any moment in time via the Model 1815-C's ZERO knob. Since dark currents drift with temperature, the ZERO should be adjusted just prior to taking any measurements. The noise or drift in the dark current sets a lower bound on the measurement resolution which can be achieved with any given detector.

If the detector temperature is constant, sensitivity changes and dark current drifts are significantly reduced. In addition, if the detector is cooled, the dark current and dark current noise will decrease. For the most accurate measurements, particularly with germanium detectors, the user should cool the detector to approximately 0 °C and control the temperature to within ± 1 °C.

3.3.3 Thermopile Detector Temperature Effects

Disk themopile based detector characteristics (Newport Corporation **High-Power** detectors) are significantly affected by temperature fluctuations arising from air flow disturbances. As the detector element is a heat measuring device, air flow disturbances often set a practical lower limit on the power that a detector can measure. In order to get the most out of any thermopile detector, be careful to shield the detector from air flow disturbances. Common sources of disturbance are air conditioners and people walking past.

3.3.4 Ambient and Stray Light

Ambient and stray light striking the detector will be measured by the Model 1815-C, and should be considered when making careful measurements. Ambient light can be distinguished from dark current (or the detector/meter noise floor) by either turning off or blocking the source *and* covering the detector face with opaque material such as a piece of black metal. Using the human hand to cover the detector is not advised because it both emits a significant amount of infrared radiation, and because it radiates a temperature significantly different from ambient. With the detector covered, a reading of the dark current may be made. Next, remove the material which is covering the detector and take another reading. The difference is the ambient light level.

The effects of ambient light are greatly reduce when using a fiber-connectorized signal input to the detector. If free-space beam measurements are desired, using an attenuator (**Low-Power** detectors have an OD3 attenuator included) will reduce stray light and often improve the source signal to ambient signal noise level. Wavelength-specific filters, such as optical cutoff, bandpass, or spike filters can also be used if the signal wavelength spectrum permits. Other techniques to reduce stray light include using apertures, placing the detector in a box or other housing to shield the surface from light (or air currents when using Newport's **High-Power** disk thermopile detectors) which is not coming from the source, and turning off room and other lights.

Note

Changes in ambient light levels can occur from such factors as turning room lights on or off, or by moving people or equipment. Remember, if you can see your detector element, then your detector can see the light bouncing off your shirt!

3.4 Performing Basic Measurements

Basic measurement techniques for using the Model 1815-C are covered in the following sections. Also included are methods of background correction and common measurement errors. In general the absolute measurement accuracy is limited by the accuracy of the detector calibration and environmental factors affecting the detector. See the appropriate detector manual for specific information on a particular detector model.

3.4.1 Making a Power Measurement

The following process describes the procedure for making a basic optical power measurement while properly removing influence of ambient light and other drift effects.

1. Set up the meter calibration factor to reflect the detector at wavelength of light you will be making your power measurement at. See Sections 2.4.4.1 and 2.4.4.2.
2. Cover or otherwise block the source that you will be measuring and adjust the Range knob until the ambient signal is displayed to three significant figures.
3. Use the ZERO knob to remove the ambient signal by zeroing the display.
4. Uncover the source and adjust the Range knob until the source power is displayed to three significant figures of accuracy.
5. Record the display value and the appropriate units from the Range knobs position. This reading is your optical power.

The process as detailed assumes that the ambient signal is not changing between when you zero the display (step 3) and when you make your measurement, (step 5). Remember though, if you can see your detector as you move around, then your detector can see you as a changing ambient signal!

3.4.2 Common Measurement Errors

The most common source of optical power measurement error are listed in Table 6 below.

Table 6 — Common Measurement Errors

Type of Error	Type of Detector	What should be done?
Radiometry	Any	Check that all of the light is actually hitting the detector.
Ambient Light	Any	Check that any ambient light was ZEROed before the measurement was made.
Wavelength Calibration	Any	Check that the Calibration Factor for the measurement wavelength is properly set.
Low Battery Power	Any	Check that meter is not indicating low BAT.
Detector Saturation	Low-Power	Check that the optical power density remains below the detector's saturation threshold.
Meter SETUP Configuration	Any	Check that the SETUP DIP switch bank is properly set up for the detector being used.

3.5 System Accuracy

The system measurement accuracy of the Model 1815-C Optical Power Meter is primarily governed by the calibration accuracy of the attached detector. The electronic accuracy of the Model 1815-C exceeds the calibration uncertainties of detectors by almost one decade. However, as NIST calibration capabilities improve, system accuracies may eventually begin to experience the influence of electronic accuracy uncertainties.

Section 4

Test, Maintenance and Troubleshooting

4.1 Maintenance Procedures

In cleaning the body of this instrument, use only a mild soap and water solution on a damp cloth.

Caution

Do not use acetone or other organic solvents on the Model 1815-C. Organic solvents attack the ABS plastic case.

4.2 Performance Verification

This section contains information to verify that the Model 1815-C electrical performance is within the specified accuracy. Model 1815-C specifications may be found at the front of this manual.

Ideally, performance verification should be performed when the instrument is first received to ensure that no damage or change in calibration has occurred during shipment. The verification procedure should also be performed whenever instrument accuracy is suspect. If the performance under these circumstances is outside specified limits, contact Newport Corporation about re-calibration.

Note

If the instrument does not meet specifications and it is still under warranty (less than 12 months since date of shipment), contact your local Newport Corporation representative or the factory to determine the action to be taken.

4.2.1 Environmental Conditions

The instrument should be operated with ambient temperature surrounding the Model 1815-C between 18°C and 28°C with a relative humidity of less than 70%.

4.2.2 Recommended Test Equipment

Equipment for verifying the performance of the Model 1815-C is listed in Table 7. Alternative equipment may be used so long as the equipment accuracy is at least as good as the specifications listed in Table 7.

Table 7 — Recommended Calibration Equipment

Description	Specification	Manufacturer	Model
Current Source	1.00 nA to 10 mA Required Accuracy <100 nA ±0.4% >100 nA ±0.1%	Keithley	220
DC Voltage Source	1 μV Resolution (Resistive voltage divider may be required)		
Digital Multimeter	1 μV Resolution Required Accuracy ±0.4%	Keithley	192

4.2.3 Initial Conditions

Before performing the verification procedures, make sure the Model 1815-C meets the following environmental criteria:

a. If the instrument has been subject to temperatures either below 18°C (65°F) or above 28°C (82°F), allow sufficient time for the instrument to reach temperatures within this range. It generally takes one hour to stabilize a Model 1815-C that is >10°C (18°F) outside of this range.

b. Turn on the Model 1815-C and allow it to warm up for 10 minutes.

4.2.4 Verification Procedures

To properly check the accuracy of the Model 1815-C, a precision current source and precision function generator are necessary. The precise currents required are obtained by using a precisely setable current source such as the Keithley Instruments Model 220 and a precisely setable Voltage Source such as the Hewlett-Packard 8904A, Function Generator.

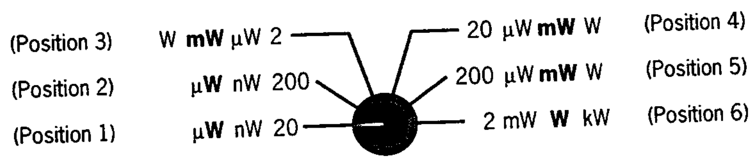


Figure 7 — Model 1815-C Range Switch Positions

a. Verifying current measurement performance:
   1. Set the Model 1815-C SETUP DIP bank to: 1, 0, 1, 0 for positions 1, 2, 3 and 4 respectively.
   2. Set the Range switch to position 1, the highest gain position. See Figure 7.
   3. Press the CAL button and adjust CAL ADJ until the display indicates 1.00 and then release the CAL button.
   4. With an open input, use the ZERO knob to adjust the display to 00.00 ±0.05.
   5. Connect the Model 1815-C to a current source.
   6. Using Table 8 as a guide, set the appropriate output currents listed and record the resulting Model 1815-C display readings.

Table 8 — Model 1815-C Current Calibration Check

Range Position	Current Supplied	Desired Reading	Actual Reading	Allowable ±Error	Expected ±Error
1	18.00 nA	18.00 nA	______	0.31 nA	0.08 nA
2	180.0 nA	180.0 nA	______	3.1 nA	0.8 nA
3	1.800 μA	1.800 μA	______	0.031 μA	0.008 μA
4	18.00 μA	18.00 μA	______	0.31 μA	0.08 μA
5	180.0 μA	180.0 μA	______	3.1 μA	0.8 μA
6	1.800 mA	1.800 mA	______	0.031 mA	0.008 mA

b. Verifying voltage measurement performance:

1. Set the Model 1815-C SETUP DIP bank to: 0, 1, 1, 0 for positions 1, 2, 3 and 4 respectively.
2. Set the Range switch to position 3, the highest gain position in the voltage mode. See Figure 7.
3. Press the CAL button and adjust CAL ADJ until the display indicates 1.00 and then release the CAL button.
4. With a shorted input, use the ZERO knob to adjust the display to 00.00±0.05.
5. Connect the Model 1815-C to a voltage source.
6. Using Table 9 as a guide, set the appropriate output voltages listed and record the resulting Model 1815-C display readings. Adjust the Range switch as required.

Table 9 — Model 1815-C Voltage Calibration Check

Range Position	Voltage Supplied	Desired Reading	Actual Reading	Allowable ±Error	Expected ±Error
3	1.800 mV	1.800 mV	______	0.034 mV	0.008 mV
4	18.00 mV	18.00 mV	______	0.34 mV	0.08 mV
5	180.0 mV	180.0 mV	______	3.4 mV	0.8 mV
6	1.800 V	1.800 V	______	0.034 V	0.008 V

4.3 Troubleshooting Guide

The following troubleshooting guide is intended to isolate and solve problems with the power meter so that, to the greatest extent possible, the return of the power meter/detector system to Newport will be unnecessary. For the problems that cannot be resolved with information in this manual, or for other situations that are not covered in this section, please see Section 5 for details on returning your entire system to Newport for service.

Table 10 — Symptom/Fault Troubleshooting Guide

Symptom	Possible Fault/Correction
Blank display.	Power switch OFF. Turn switch ON.
	Batteries dead. Replace batteries per Section 2.4.1.
BAT indicator lit.	Batteries voltage is low. Replace batteries per Section 2.4.1.
Display value does not change.	CAL button depressed. Release CAL button.
Display indicates ±1	Signal overflow. Adjust Range knob clockwise.
Reading is different than expected.	See Table 6 Common Measurement Errors. Section 3.4.2.

Section 5
Factory Service

5.1 Introduction

This section contains information regarding obtaining factory service for the Model 1815-C Optical Power Meter. The user should not attempt any maintenance or service of this instrument and/or accessories beyond the procedures given in Section 4: Test, Maintenance and Troubleshooting. Any problems which cannot be resolved using the guidelines listed in Section 4 should be referred to Newport Corporation factory service personnel. Contact Newport Corporation or your Newport representative for assistance.

The Model 1815-C contains no user serviceable parts other than batteries, see Section 2.4.1. Its calibration accuracy is warranted for a period of 1 year. After 1 year, the unit should be returned to Newport Corporation for recalibration.

5.2 Obtaining Service

To obtain information concerning factory service, contact Newport Corporation or your Newport representative. Please have the following information available:

1. Instrument model number (On front panel)
2. Instrument serial number (On rear panel)
3. Description of the problem.

If the instrument is to be returned to Newport Corporation, you will be given a Return Authorization Number, which you should reference in your shipping documents.

Please fill out the service form, located on page 19, and have the information ready when contacting Newport Corporation. Return the completed service form with the instrument.

5.3 Service Form

Newport Corporation
U.S.A. Office: 714/863-3144
FAX: 714/253-1800

Name ______________________________ RETURN AUTHORIZATION # ______________

Company ______________________________ (Please obtain prior to return of item)

Address ______________________________ Date ______________________

Country ______________________________ Phone Number ______________________

P.O. Number ______________________________ FAX Number ______________________

Item(s) Being Returned:

Model # ______________________ Serial # ______________________

Description: ____

Reason for return of goods (please list any specific problems) ______________________

____

Please complete the below, as appropriate.

List all control settings and describe problem: ______________________

____

____

______________________________________ (Attach additional sheets as necessary).

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Describe signal source. If source is a laser, describe output mode, peak power, pulse width, repetition rate and energy density.

Where is the measurement being performed?

(factory, controlled laboratory, out-of-doors, etc.) ______________________

What power line voltage is used? ______________ Variation? ______________

Frequency? ______________ Ambient Temperature? ______________

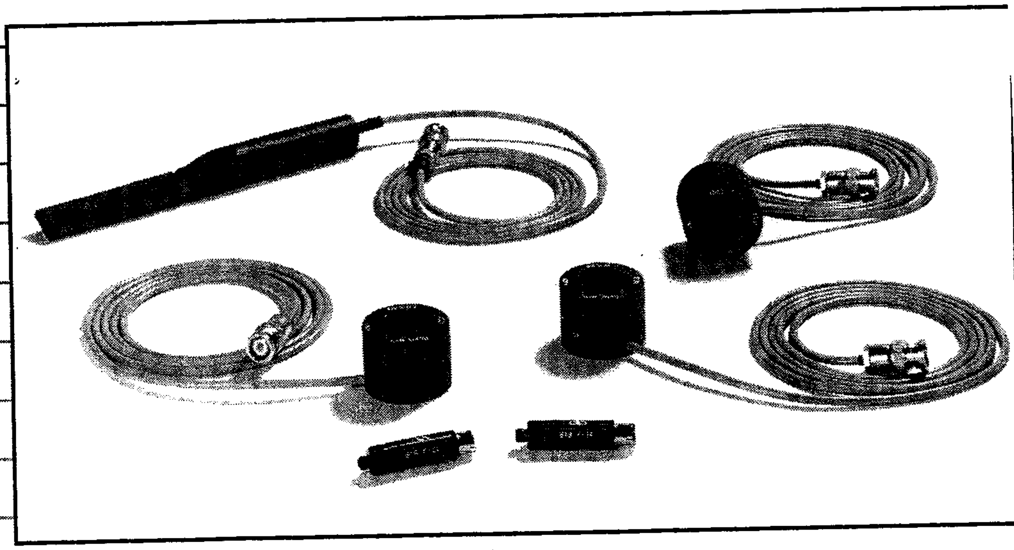
Variation? ______________ °F. Rel. Humidity? ______________ Other? ______________

Any additional information. (If special modifications have been made by the user, please describe below).

____

____

818 Series Photodetector Guide



OPERATOR
MANUAL

Newport

Section 1
General Information

This guide contains information necessary for using Model 818 Series photodetectors. A separate data sheet is provided with each detector. Some detectors are also provided with individual calibration data. Please read through the guide before attempting to make optical power measurements.

CAUTION

Applied voltage exceeding the detector specification, forward bias, or optical power exceeding the damage threshold can damage the detector.

1.1 Unpacking and Inspection

The items included with every order are given on the data sheet. Please check to be sure that all items are present and are received in good condition.

1.2 Calibration Services

Newport's calibration services calibrate (or recalibrate) photodetectors. These services provide the calibration data in a written calibration record and in a programmable read only memory (PROM) when appropriate for use with a Newport Power Meter.

1.3 Use with a Newport Power Meter

The photodetector consists of a photodiode attached to a cable terminated with a standard BNC connector and packaged within a protective housing. Some housings provide a place for attaching accessories such as attenuators.

The BNC termination can be directly connected to a Newport Power Meter.

1.4 Cleanliness

Care should be taken not to touch the photodiode window with bare fingers. Contaminants may cause inaccurate measurements, particularly at ultraviolet wavelengths where absorption is common. Lightly clean the detector window with reagent grade alcohol and a soft cotton cloth.

Potentially large measurement errors can be generated through scratches, digs and coating damage on detector optical surfaces. The magnitude of an error typically varies directly with the ratio of the intercepted area of the "scratch" relative to the area of the optical beam.

NOTE

Kleenex and chem-wipes contain wood and fiber glass (respectively) and will scratch optical surface.

1.5 Temperature and Humidity

The photodiode sensitivity increases with temperature for wavelengths longer than the peak response wavelength. Typical temperature coefficients are shown in the data sheet Graph 4. Best results will be obtained by keeping the detector near the calibration temperature of 25°C. The temperature range 0 – +50°C should not be exceeded and the detector should not be exposed to humidity levels greater than 70% or possible damage to the photodiode could occur.

NOTE

See detector data sheet for detector specific graphs and figures which are not included in the guide.

Section 2
Calibration Accuracy and Limitations

2.1 Spectral Response

The response of the detector depends on the wavelength of the incident light. The photodiode is transparent for photon energies less than the band gap which determines the long wavelength infrared sensitivity limit. The short wavelength limit is determined by the photodiode manufacturing process and possibly, in the case of silicon photodiodes, by strong window absorption. The photodiode response is commonly measured in amps of photocurrent per watt of incident optical power. Typical response curves for the photodetector is shown on the data sheet. The transmission of the attenuator (if provided) may vary considerably across the detector's range.

2.2 Calibration Accuracy and Service

Statement of Calibration

The accuracy and calibration of this photodetector are traceable to the NIST or NPL through equipment which is calibrated at planned intervals by comparison to certified standards maintained at Newport Corporation.

Newport Corporation calibrates its detectors using secondary standards directly traceable to the United States National Institute of Standards and Technology or National Physical Laboratory. At wavelengths where appropriate standards are not available, Newport calibrates its detectors by comparison to detectors calibrated with thermal detectors. The absolute accuracy of the photodetector calibration is indicated in the calibration certificate.

Individual detector response can change with time at different wavelengths, especially in the ultraviolet, and should be returned for recalibration at 1 year intervals to assure confidence in the accuracy of the measurement.

For recalibration services, see the Accessories and Services information.

2.3 Uniformity

Fabrication processes may cause the response of the detector to vary slightly over the detector surface. Calibration involves illumination of approximately 70% of the detector central active diameter. Optical signals being measured should illuminate the same area. Care should be taken not to overfill the detector if accuracy is to be maintained.

2.4 Saturation

A typical photodiode output current vs. illuminance curve for the unbiased photodetector is shown on the datasheet graph 3. For low optical power, the photocurrent is proportional to the optical signal incident on the photodiode and the photocurrent linearly increases with optical power. For high optical powers saturation of the detector begins to occur and the response signal is no longer linearly proportional to the incident power. Optical power measurements must be made in the linear region to be valid.

NOTE

The saturation is "soft", i.e. the detector output does not suddenly stop increasing, but the rate of increase slows. For Gaussian and other signals with spatially varying intensities, local saturation may occur. The onset of saturation is not always obvious and is a common source of inaccurate measurements.

To determine if the detector is saturating, follow the steps below:

1. Measure the photodetector current (or power), and record this value (A).
2. Place a filter or attenuator of known transmission (T) in the beam path. Record the current again (B). A filter transmission of 0.001 is a convenient choice.
3. The power with the filter in place should be the product of the power measured without the filter and the transmission of the filter, i.e. B = A x T.

The transmission (T) of the filter can be determined by following the steps below:

1. Reduce the optical power to a level low enough to avoid saturation, but high enough that, when it is reduced by the filter it can still be accurately measured.
2. Follow steps 1 and 2 in the procedure above.
3. Calculate the ratio T = B/A to determine the transmission of the filter at the wavelength of light used for the measurement.

The calibrated filter (or attenuator) can be used with the detector to measure the power of higher power beams.

2.5 Saturation with Pulsed Power Measurements

Saturation effects when using pulsed lasers are a complex phenomenon, and depends upon the wavelength, peak power, pulse shape, average power, repetition rate, and on the detection circuit. However, the test for saturation described immediately above should be used whenever pulsed power measurements are being made. Alternatively, when the detector is used for observing pulse shape, placing an attenuator in the beam should affect only the pulse amplitude, not the pulse shape.

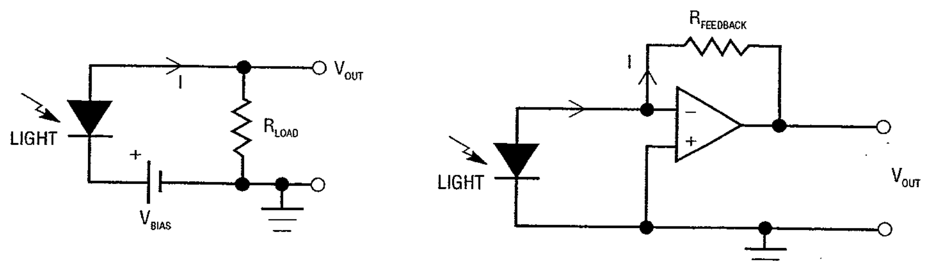
2.6 Reflections

The photodetector surface, window material and the attenuator all reflect light. The amount of reflected light depends upon the angle of incidence and the polarization of the beam. Reflected light does not get absorbed by the detector, and therefore is not included in the detector signal. The Newport detector and attenuator calibration include the loss due to reflection for incoherent light incident normal to the detector. For accurate power measurements the detector should therefore be used at near normal incidence.

2.7 Photodiode Operation

When a photon is absorbed in the photodiode, an electron-hole pair is formed within the device and a voltage is developed across the diode junction. If the photodiode terminals are connected a photocurrent proportional to the light intensity will be generated. Measuring this photocurrent provides a measurement of the optical power incident upon the detector.

Figures 3(a) and 3(b) show common methods of measuring the photocurrent generated by the photodiode. In circuit (a) a bias voltage is used to drive the current through a load resistor and the voltage drop is measured. This is called the photoconductive mode of operation. The bias voltage enhances the speed of response and the linearity of the photocurrent generation but introduces additional noise and dark current. Circuit (b) shows the use of a Op-amp to enable unbiased photocurrent measurement. Operation with zero bias is called the photovoltaic mode because the photodiode is actually generating the bias voltage. This is the method used in Newport Power Meters. The feedback resistance in circuit (b) is selectable.



(a) Reverse Bias Circuit
Photoconductive Mode — improved time response and linearity

(b) Op-Amp Circuit
Photovoltaic Mode — reduced noise

Figure 3 — Photodiode Operational Circuits

2.8 Low Power Measurement Considerations

Measurements of very low power optical sources are possible with the photodetector. To use the detector properly and achieve accurate results requires the understanding of a number of effects that limit the device performance, which are discussed in paragraphs 2.9 and 2.10.

2.9 Noise Characteristics

The lower limits of optical detection are determined by the noise characteristics of the detector and/or amplifier. Theory predicts that the photodiode noise is largely thermal (Johnson) noise associated with the effective resistance of the photodiode and shot noise from dark current.

The dark current at 10 mV bias voltage is measured and used to define the effective resistance of the diode, the shunt resistance given in the data sheet:

$$R_{shunt} = V_{bias}\,(10\ \text{mV}) / I_{dark}.$$

Ideally an input amplifier connected as in Figure 3 (b) would have no offset voltage and there would be no dark current. In practice though, a small bias usually exists, and even at zero applied bias a small dark current is present. The maximum dark currents when used with Newport power meters are given in the specifications. The drift in this dark current is generally much smaller than the dark current so effective cancellation is often possible.

For non-DC measurements the light detection limit is more generally expressed as the intensity of light required to produce a current equal to the noise current. This is called the noise equivalent power (NEP) and has units of optical power divided by the square root of the detector bandwidth:

$$W/\sqrt{Hz}.$$

The NEP varies inversely with the spectral response of the photodiode and depends on the wavelength, λ, the noise frequency, f, and bandwidth, Δf.. NEP is therefore defined as NEP(λ, f, Δf).

Lock-In amplifier techniques can be used to approach the NEP.

2.10 Temperature and Ambient Lighting

Drifts in temperature and ambient lighting can cause significant variations in diode response and amplifier performance for low power measurements, particularly for wavelengths longer than the bandgap (shown on Graph 1). It is therefore important to provide as constant environmental conditions as practical, including consideration of air conditioning and roomlighting effects.

In addition the noise and dark current generally increase exponentially with detector temperature so it is best to keep the temperature close to 25°C.

Some 818 Series photodetectors (e.g. Models 818-SL and 818-IR) have threads for the attachment of accessories. With these models, the effects of ambient lighting can be minimized by using the Model 818-FA Fiber Adapter Holder with the appropriate FP3-CA series fiber adapter when measurements of power in fiber optics are being made. If free space beam measurements are desired, using an attenuator will reduce stray light and often improve the ratio of signal to background. Wavelength specific filters, such as optical cutoff, bandpass, or spike filters can also be used if the signal wavelength spectrum permits. Other techniques to reduce stray light include using apertures to admit only the laser beam, placing the detector in a box to shield the surface and turning off the room and other lights.

2.11 Using the Detector for Non-CW measurements

When the photodetector is used with a Newport Power Meter it is operated essentially without bias voltage, as depicted in Figure 3 (b). The effective time constant of the detector-amplifier combination may be much slower than the characteristic time of the signal. Nonetheless, if the detector-amplifier combination does not become saturated, effective integration of the signal will occur, and accurate energy measurements of very short pulses can be made.

It is also possible to use the photodiode for the display of the temporal behavior of an optical signal with an oscilloscope. The detector can be connected directly to the scope input or a simple reverse bias circuit can be used. Reverse biasing will improve the time response and increases dark current, the range of wavelength response and the range of linearity of the detector. The correct biasing circuit is depicted schematically in Figure 3 (a) and is shown pictorially in Figure 4. By varying the load resistance, R_L, adjustment can be made for different optical powers. A large load enables the measurement of low power signals but will increase the probability of saturation and slow the time response. Saturation is evident when the voltage measured by the oscilloscope is greater than the bias voltage and results in "flat-topped" signals.

CAUTION

Forward biasing the detector can destroy the diode.
Reverse bias should not be used in conjunction with the Newport Power Meters and in no circumstances should the bias voltage exceed the breakdown voltage of the photodiode.

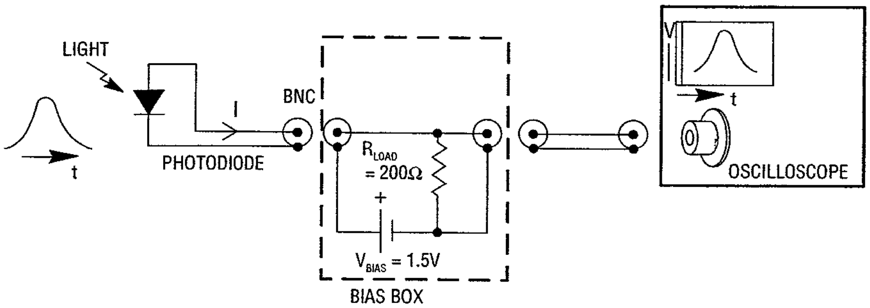


Figure 4 — Schematic of the Reverse Bias Circuit

Newport
Newport Corporation
1791 Deere Avenue
Irvine, CA 92606
Phone: (949) 863-3144
Fax: (949) 253-1800

PA2358
CERTIFICATION NUMBER

ISO 9001
FM 27207

CERTIFICATION OF CALIBRATION

Model No: 1815-C
Serial No: 3892
Description: Optical Power Meter
Customer Name: Initial Purchaser
Address:
Calibrated Per Procedure No: PTP-19450

Environment Conditions

Temperature: 75.5 °F
Relative Humidity: 54 %

Standards Used

Model	Serial or ID No.	Description	Cal Due Date	Calibration Traceability Number
Keithley 263	0568422	Current Source	15-JAN-2002	1447323
HP 34401A	US36017812	Multimeter	15-JAN-2002	1447318

Newport certifies that the calibration that was performed using Standards that are traceable to the National Institute of Standards and Technology (NIST), other recognized national standards laboratories, using natural physical constants, or ratio calibration techniques. The calibration complies with ANSI/NCSL Z540-1-1994, ISO Guide 25 and ISO-9001. This certificate shall not be reproduced except in full, without the written approval of Newport. Specific information concerning parameters and measurements in attachment(s). Calibration ratio is at least 4:1 unless otherwise stated.

Calibration Date: 10-Jul-2001 (DD-MMM-YYYY)
Calibrated By: M. Bollinger (Print/Sign)
Reviewed By: M. Bollinger
Title: Technician

Newport
SN 3892
CALIBRATED BY MB
DATE 10 JUL 01
DUE 10 OCT 02
DD MMM YY

Please remove and apply calibration sticker to the instrument as required.

BF-09951 (11/99)
P/N 21650-01 Rev. F

Newport
Newport Corporation
1791 Deere Avenue, Irvine, CA 92606
Telephone: 949-863-3144
Facsimile: 949-253-1800

Detector Calibration Report

Detector Model Number:	***818-SL***
Detector Serial Number:	***10551***
Attenuator Serial Number:	***10551***
Operator:	***Chau P.***
Calibration Traceable to NIST Number:	***844/264788-01***
Calibration Date:	***24-APR-2001***
Calibration Temperature:	***24.8 ± 0.5 °C***

Newport
SN 10551
CALIBRATED BY CP
DATE 24 APR 01
DUE 24 JUL 02
DD MMM YY

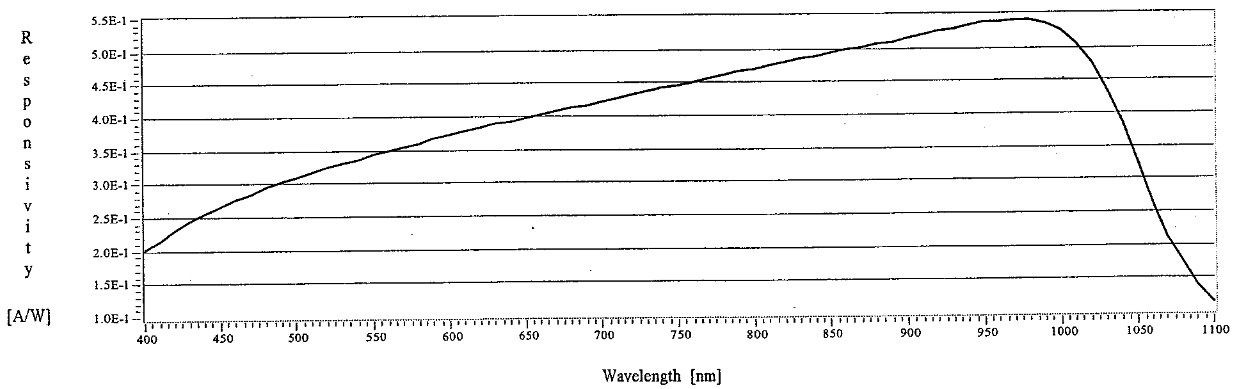
Please remove & apply calibration sticker to the instrument as required.

Complies with **ANSI/NCSL Z540-1-1994**

Table 1. Responsivity [A/W]: Detector Without Attenuator

Lambda	0	10	20	30	40	50	60	70	80	90
400	2.0101E-1	2.1595E-1	2.3096E-1	2.4407E-1	2.5597E-1	2.6658E-1	2.7664E-1	2.8587E-1	2.9439E-1	3.0252E-1
500	3.1014E-1	3.1735E-1	3.2416E-1	3.3069E-1	3.3693E-1	3.4367E-1	3.4983E-1	3.5566E-1	3.6114E-1	3.6656E-1
600	3.7205E-1	3.7786E-1	3.8327E-1	3.8839E-1	3.9234E-1	3.9652E-1	4.0191E-1	4.0728E-1	4.1232E-1	4.1722E-1
700	4.2243E-1	4.2720E-1	4.3212E-1	4.3706E-1	4.4203E-1	4.4685E-1	4.5200E-1	4.5668E-1	4.6126E-1	4.6603E-1
800	4.7052E-1	4.7529E-1	4.7986E-1	4.8444E-1	4.8896E-1	4.9341E-1	4.9802E-1	5.0242E-1	5.0712E-1	5.1060E-1
900	5.1564E-1	5.2020E-1	5.2572E-1	5.2915E-1	5.3423E-1	5.3930E-1	5.4036E-1	5.4137E-1	5.4068E-1	5.3582E-1
1000	5.2473E-1	5.0660E-1	4.7735E-1	4.3772E-1	3.8532E-1	3.2657E-1	2.6264E-1	2.1210E-1	1.7379E-1	1.4111E-1
1100	1.1284E-1									

Responsivity versus Wavelength
Detector Without Attenuator



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Newport Corporation
1791 Deere Avenue, Irvine, CA 92606
Telephone: 949-863-3144
Facsimile: 949-253-1800

Detector Calibration Report

Detector Model Number: ***818-SL***

Detector Serial Number: ***10551***

Attenuator Serial Number: ***10551***

Table 3. Calibration Factors: Detector Without Attenuator

Lambda	0	10	20	30	40	50	60	70	80	90
400	4.975E+0	4.631E+0	4.330E+0	4.097E+0	3.907E+0	3.751E+0	3.615E+0	3.498E+0	3.397E+0	3.306E+0
500	3.224E+0	3.151E+0	3.085E+0	3.024E+0	2.968E+0	2.910E+0	2.859E+0	2.812E+0	2.769E+0	2.728E+0
600	2.688E+0	2.647E+0	2.609E+0	2.575E+0	2.549E+0	2.522E+0	2.488E+0	2.455E+0	2.425E+0	2.397E+0
700	2.367E+0	2.341E+0	2.314E+0	2.288E+0	2.262E+0	2.238E+0	2.212E+0	2.190E+0	2.168E+0	2.146E+0
800	2.125E+0	2.104E+0	2.084E+0	2.064E+0	2.045E+0	2.027E+0	2.008E+0	1.990E+0	1.972E+0	1.958E+0
900	1.939E+0	1.922E+0	1.902E+0	1.890E+0	1.872E+0	1.854E+0	1.851E+0	1.847E+0	1.850E+0	1.866E+0
1000	1.906E+0	1.974E+0	2.095E+0	2.285E+0	2.595E+0	3.062E+0	3.808E+0	4.715E+0	5.754E+0	7.087E+0
1100	8.862E+0									

Table 4. Calibration Factors: Detector With Attenuator

Lambda	0	10	20	30	40	50	60	70	80	90
400	7.378E+3	6.637E+3	6.179E+3	5.534E+3	5.464E+3	4.968E+3	4.402E+3	4.291E+3	4.417E+3	4.546E+3
500	4.595E+3	4.567E+3	4.437E+3	4.236E+3	4.030E+3	3.938E+3	3.967E+3	4.094E+3	4.262E+3	4.352E+3
600	4.268E+3	4.112E+3	3.953E+3	3.857E+3	3.831E+3	3.769E+3	3.556E+3	3.247E+3	2.841E+3	2.458E+3
700	2.199E+3	2.052E+3	1.966E+3	1.911E+3	1.875E+3	1.853E+3	1.838E+3	1.831E+3	1.828E+3	1.828E+3
800	1.832E+3	1.836E+3	1.842E+3	1.850E+3	1.860E+3	1.871E+3	1.883E+3	1.897E+3	1.923E+3	1.943E+3
900	1.958E+3	1.972E+3	1.989E+3	2.009E+3	2.027E+3	2.041E+3	2.068E+3	2.096E+3	2.126E+3	2.173E+3
1000	2.242E+3	2.343E+3	2.502E+3	2.738E+3	3.107E+3	3.645E+3	4.491E+3	5.504E+3	6.638E+3	8.089E+3
1100	9.992E+3									

Wavelength Range	Accuracy Over the Range WITHOUT the Attenuator	Accuracy Over the Range WITH the Attenuator
400 - 1100	±2%	±2%

REV5.3a

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Detector Serial Number: ***10551***

Attenuator Serial Number: ***10551***

Table 2. Responsivity [A/W]: ***Detector With Attenuator***

Lambda	0	10	20	30	40	50	60	70	80	90
400	1.3555E-4	1.5067E-4	1.6184E-4	1.8069E-4	1.8303E-4	2.0129E-4	2.2719E-4	2.3305E-4	2.2642E-4	2.1999E-4
500	2.1762E-4	2.1897E-4	2.2537E-4	2.3607E-4	2.4811E-4	2.5397E-4	2.5208E-4	2.4427E-4	2.3465E-4	2.2978E-4
600	2.3431E-4	2.4319E-4	2.5295E-4	2.5924E-4	2.6099E-4	2.6535E-4	2.8124E-4	3.0796E-4	3.5198E-4	4.0690E-4
700	4.5475E-4	4.8731E-4	5.0876E-4	5.2333E-4	5.3339E-4	5.3968E-4	5.4413E-4	5.4604E-4	5.4697E-4	5.4706E-4
800	5.4587E-4	5.4471E-4	5.4290E-4	5.4061E-4	5.3765E-4	5.3445E-4	5.3094E-4	5.2722E-4	5.2010E-4	5.1458E-4
900	5.1060E-4	5.0720E-4	5.0289E-4	4.9784E-4	4.9324E-4	4.8995E-4	4.8346E-4	4.7707E-4	4.7045E-4	4.6013E-4
1000	4.4600E-4	4.2685E-4	3.9967E-4	3.6525E-4	3.2184E-4	2.7434E-4	2.2266E-4	1.8169E-4	1.5064E-4	1.2363E-4
1100	1.0008E-4