
Precipitation Imaging Probe

Operator Manual

DOC-0120 Rev K



2545 Central Avenue
Boulder, CO 80301-5727 USA

Copyright © 2012 Droplet Measurement Technologies, Inc.

**2545 CENTRAL AVENUE
BOULDER, COLORADO, USA 80301-5727
TEL: +1 (303) 440-5576
FAX: +1 (303) 440-1965
WWW.DROPLETMEASUREMENT.COM**

All rights reserved. No part of this document shall be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without written permission from Droplet Measurement Technologies, Inc. Although every precaution has been taken in the preparation of this document, Droplet Measurement Technologies, Inc. assumes no responsibility for errors or omissions. Neither is any liability assumed for damages resulting from the use of the information contained herein.

Information in this document is subject to change without prior notice in order to improve accuracy, design, and function and does not represent a commitment on the part of the manufacturer. Information furnished in this manual is believed to be accurate and reliable. However, no responsibility is assumed for its use, or any infringements of patents or other rights of third parties, which may result from its use.

Trademark Information

All Droplet Measurement Technologies, Inc. product names and the Droplet Measurement Technologies, Inc. logo are trademarks of Droplet Measurement Technologies, Inc.

All other brands and product names are trademarks or registered trademarks of their respective owners.

Warranty

The seller warrants that the equipment supplied will be free from defects in material and workmanship for a period of one year from the confirmed date of purchase of the original buyer. Service procedures and repairs are warranted for 90 days. The equipment owner will pay for shipping to DMT, while DMT covers the return shipping expense.

Consumable components, such as tubing, filters, pump diaphragms, and Nafion humidifiers and dehumidifiers are not covered by this warranty.

CONTENTS

1.0	Product Description	5
1.1	Introduction	5
1.2	Instrument Components	5
1.3	PIP Specifications.....	6
1.4	Electrical Specifications	6
1.5	Physical Specifications.....	7
1.6	Operating Limits	7
2.0	Theory of Operation	7
2.1	Data Transmission	8
3.0	Other Instrument Components	9
3.1	System Performance Sensors.....	9
3.2	PIP Heaters	9
3.2.1	<i>System Power Bus Heaters</i>	9
3.2.2	<i>Anti-Ice Bus Heaters</i>	10
4.0	Particle Analysis and Display System (PADS)	11
5.0	Instrument Troubleshooting and Repair	13
5.1	Troubleshooting with Housekeeping Channels	13
5.2	Power Problems.....	15
5.3	Image and Data Problems	18
5.3.1	<i>Varieties of Image Problems</i>	18
5.3.2	<i>Background Information on Diode Array Board</i>	18
5.4	Contacting DMT regarding PIP Problems	19
6.0	Verifying PIP Calibration with the Spinning Disk Calibrator.....	20
Appendix A: Revisions to Manual.....		21
Appendix B: DMT Instrument Locator—Operator Guide		22
	Purpose.....	22
	Installation.....	22
	Operation	22

Figures and Tables

Figure 1: Precipitation Imaging Probe	5
Figure 2: Particle Imaging with PIP Probe.....	8
Figure 3: PIP Objective Lens Heater	10
Figure 4: PIP Arm-Tip Heater	11
Figure 5: PIP Data Displayed in PADS.....	12
Table 1: Acceptable Values for Diode Voltages 1, 32, and 64 when No Particles are Present.....	13
Figure 6: 28-Volt LED	16
Figure 7: LEDs for ± 5 or ± 15 Voltages	17
Figure 8: PIP Backplane Board.....	17
Figure 9: Instrument Locator	23

1.0 Product Description

1.1 Introduction

The Precipitation Imaging Probe (PIP) is a 1-Dimensional sizing instrument with 2-Dimensional imaging, incorporating a laser and a diode array to characterize cloud parameters. Full specifications of the PIP are given in Section 1.3.

The Particle Analysis and Display System (PADS), with an intuitive graphical user interface at the host computer, provides powerful control of measurement parameters while simultaneously displaying real-time size distributions, images and derived parameters. All data interfaces are done via line drivers meeting the RS-422 electrical specification, allowing cable lengths of up to 100 meters.

1.2 Instrument Components

Precipitation Imaging Probe (PIP), flight canister, calibration spinning disk, dust cover, and custom shipping case are standard.



Figure 1: Precipitation Imaging Probe

1.3 PIP Specifications

Technique:	Optical Array Probe (64 element: 62 sizing elements, end diodes reject)
Size Range:	100 μm – 6.2 mm (100 μm resolution)
Sample Area:	260 mm x 6.2 mm
Number Concentration Range:	0 – 100 cm^{-3}
Air Speed Range:	0 – 200 ms^{-1}
Number of Size Bins:	62
Sampling Frequency:	Asynchronous and 0.1 to 10 Hz. 1 second sampling is typical
Laser Wavelength:	660 nm
Data System Interface:	Two channels: RS-422: 56,000 Baud Rate; High Speed Serial, 4×10^6 Baud Rate (RS-422 only)
Auxiliary Parameters:	N/A
Calibration:	Precision glass beads and spinning glass disk with opaque dots of known size

1.4 Electrical Specifications

There are two circuits, which are powered through the canister connections, where each circuit has its own pair of contacts. The circuits are called System Power and Anti-Ice Power.

The Anti-Ice circuit should be “squat switch” controlled, so that the de-icing heaters will only be powered when the aircraft is airborne. If the de-icing heaters were to be powered while the aircraft was stationary, they would soon overheat and burn out, requiring repair. Anti-Ice Power requires 7.0 amps of 28VDC current.

System Power for the PIP can be either 28VDC or 115VAC, but must be specified at the time the probe is ordered; the probe is then built for one supply voltage or the other, and cannot be changed in the field. The following assumes that System Power is 28VDC, the most common configuration:

Voltage and current typical specifications:

- Anti-Ice Power: < 9.0 A at 28 VDC
- System Power: 2.0 A at 28 VDC

1.5 Physical Specifications

1. PIP probe outside of canister: 10.5 lbs / 4.8 kg
2. PIP probe in DMT canister: 21 lbs / 9.5 kg
3. PIP probe in generic canister: 25 lbs / 11.4 kg

1.6 Operating Limits

1. Temperature: -50 to +50° C
2. Altitude: 50,000 feet
3. Humidity: 0 -100%

2.0 Theory of Operation

The PIP design is based on established optical imaging techniques whereby images of particles passing through a collimated laser beam are projected onto a linear array of 64 photodetectors. The presence of a particle is registered by a change in the light level on each diode. The PIP registers the change as either “On” or “Off,” where “On” is when the light level decreases below 50%. The registered changes in the photodetectors are stored in a buffer at a rate consistent with probe velocity of particles passing through the beam and the size resolution. Particle images are reconstructed from individual “slices,” where a slice is the state of the 64-element linear array at a given moment in time. A slice must be stored each time interval that the particle advances through the beam a distance equal to the resolution of the probe.

The laser produces an oval 50 mW beam illuminating the diode array. Whenever a particle passes through the laser beam, its shadow is optically magnified onto a 200-pitch, 64-element photo-diode array.¹ The PIP determines the particle’s size based on how many diodes in the array its shadow obscures. Particles shadowing an end diode (i.e., diode number one or sixty-four) are rejected from the sizing routine but will generate a 2D image. The size range for PIP-detected particles ranges from 100 microns to 6200 microns.

¹ “Pitch” refers to the distance from one diode’s center to the next diode’s center on a photodiode array. The array’s pitch is constant regardless of the PIP’s resolution, so the optical magnification factor varies accordingly.

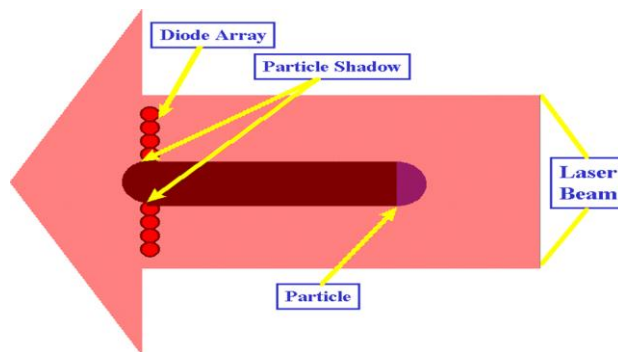


Figure 2: Particle Imaging with PIP Probe

2.1 Data Transmission

For one-dimensional (1D) sizing data, the digital signal processor monitors the transition of the particle shadow over the diode array, and uses the maximum detected width to determine the correct size bin for the particle. The processor also stores the cumulative number of particles of each size during the sample period (a frequency distribution) as well as the number of end-diode rejected particles. The 1D statistical data, when polled, is sent to the host processor. PADS or similar software then stores and displays this information. 1D data transmission is synchronous, meaning that information between the PIP and the host computer is sent at regular, synchronized intervals.

2D image data are compressed using run-length encoding and transmitted to the host computer. 2D data transmission is asynchronous, meaning that data are sent intermittently. Along with the image data, the host computer receives particle header information that contains the precise beginning and end location of every particle, the time the particle was measured relative to instrument start-up, and the total number of particles received. Whenever the image and header data fill a 4096-byte buffer, these data are sent to the host, and the host software de-compresses a portion of this data for image display to the screen and stores the entire compressed information to disk.

3.0 Other Instrument Components

In addition to the PIP's optical components with associated detectors and signal conditioning electronics, the instrument includes numerous other elements. These components are dedicated to monitoring system performance and providing heat to prevent icing or fogging of the optics while optimizing performance of the probe.

3.1 System Performance Sensors

The PIP measures several system performance variables. These are stored in the following housekeeping channels:

- Diode 1 volts
- Diode 64 volts
- Diode 32 volts
- DSP Board Temp
- Laser Current
- Laser Power

For more information, see section 5.1.

3.2 PIP Heaters

The PIP has both system power bus and anti-ice bus heaters.

3.2.1 System Power Bus Heaters

The System Power bus has required heaters for warming the laser, pressure transducers, and some electronic components. These heaters ensure that optical and electronic equipment is operating within its specified temperature range. The System Power bus also has an anti-condensation heater, the objective lens heater, which is described below. System Power consumption is approximately 100W.

3.2.1.1 *Objective Lens Heater*

Location: One heater on each PIP arm.

Specs: Curved ribbon heater, 10W at 28VDC, .36 A, 78.4 ohms each, DMT P/N HTR-0097.
Other: This heater keeps condensation off the optics. It is located on the System Power bus.

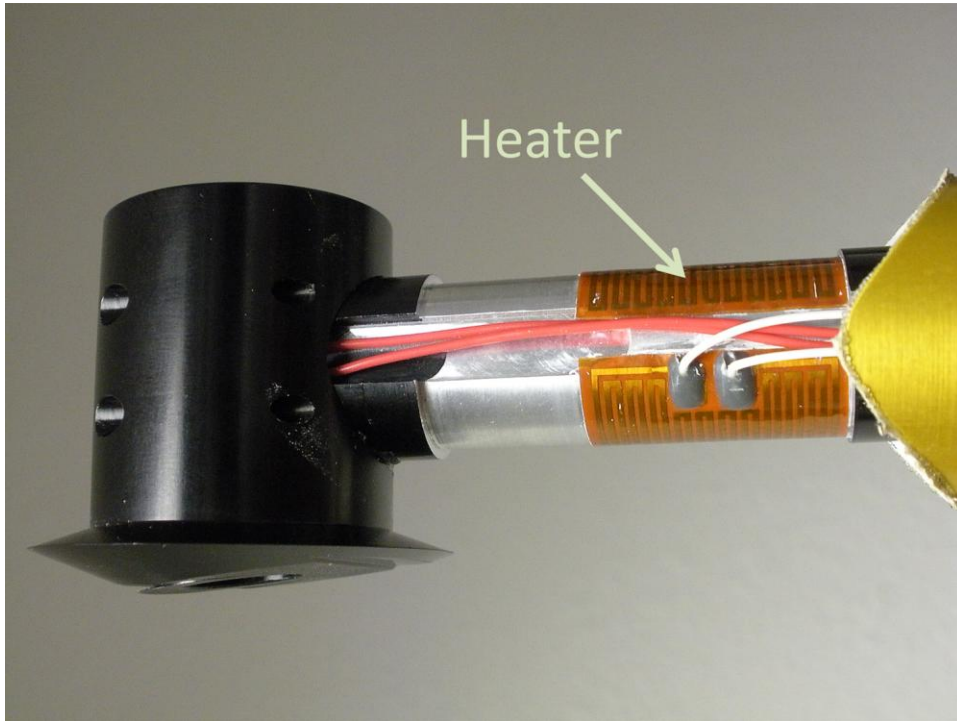


Figure 3: PIP Objective Lens Heater

3.2.2 Anti-Ice Bus Heaters

Most anti-ice and anti-condensation heaters are on a separate aircraft-controlled bus and should be activated only during flight and turned off before landing. More information about these heaters appears below. Note that this information is for the standard 28V anti-ice busses. Specifications are different for 115V systems; contact DMT for details.

3.2.2.1 Arm-Tip Heaters

Location: One heater on tip of each PIP arm (see Figure 4).
Specs: Curved ribbon heater, 80W at 28VDC, 2.8A, 9.8 ohms each, DMT P/N HTR-0056.
Total power for both heaters: 160W at 28VDC, 5.7A.

Other:

These heaters have two purposes—to de-ice the arm tips, and to keep the sapphire windows and 45-degree mirrors from fogging.

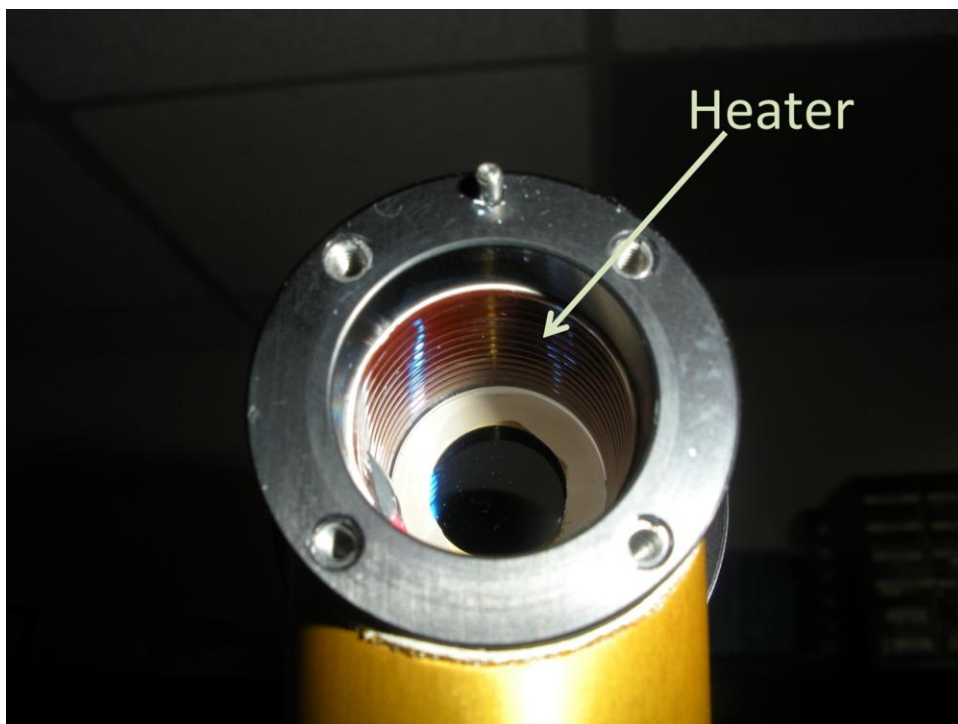


Figure 4: PIP Arm-Tip Heater

4.0 Particle Analysis and Display System (PADS)

PADS is a Windows-based, LabVIEW software package that is the default interface system for the PIP. It offers attractive display and analysis features, and data acquired with PADS can be stored to a file for later analysis. The program also stores all configuration information as a file header, so users can easily determine the system settings at the time of data acquisition.

Figure 5 shows PADS displaying data acquired with the PIP.



Figure 5: PIP Data Displayed in PADS

PADS is also used to configure the set-up for the PIP. See the *PADS Operator Manual (DOC-0116)* and the *PADS PIP Module (DOC-0197)* for configuration and display details.

5.0 Instrument Troubleshooting and Repair

If the PIP does not seem to be functioning properly, it is advisable to begin troubleshooting by analyzing the instrument's housekeeping data (see section 5.1). You can also examine various components of the instrument itself. The PIP electronics are modular in design, which allows for in-field troubleshooting and repair. There are four printed circuit boards (PCBs) that make up the PIP probe: the backplane, power module, DSP module, and diode array. The PIP backplane and power module are useful in identifying power problems; see section 5.2. The diode array board is the most likely cause of image problems, which are described in section 5.3. Finally, the instrument's terminal strip can be used to determine if the PIP's heaters are functioning properly.

Note that schematics for each of the PIP's PCBs are shipped with the probe. See *Appendix B: PIP Block Diagram* for a functional diagram of the PIP modules.

5.1 Troubleshooting with Housekeeping Channels

Several of the PIP's housekeeping channels offer information that helps diagnose instrument health. These are described below. For information on how to convert the housekeeping analog-digital values returned by the PIP into the units given below, see the table at the end of this section. If you have PADS, the program will have already performed these conversions.

Diode Voltages 1, 32, and 64 store the representative power level of the laser light illuminating the corresponding diode on the PIP's photodetector array. These indicators are used as a diagnostic. A very low or high voltage indicates a problem with the instrument, as does the appearance of one diode voltage being much higher or lower than the others. See the table below for acceptable values when no particles are present.

Diode #	(1)	(32)	(64)
Minimum Measured	1.5	1.2	1.5
Mean Measured	2.3	2.6	2.3
Maximum Measured	3	3.7	3

Table 1: Acceptable Values for Diode Voltages 1, 32, and 64 when No Particles are Present

A chronic low voltage may indicate a blockage of photodetector array. Although much less likely, a low voltage may also indicate the laser is nearing end of its life. In this case, the laser current reading will likely be higher than usual. A misalignment of the laser on the array will be seen as an imbalance in the #1 and #64 diode voltages with respect to one another.

DSP Board Temp (C) stores the temperature at the digital signal processing board. In flight situations, the DSP Board Temperature will typically be considerably higher than the ambient temperature. This is because the power consumption of the electronics raises the board's temperature and because the board is encased in an insulating canister. A DSP Board temperature that is routinely above 50°C will shorten the life of the laser.

Laser Current stores the electrical current flowing through the PIP's laser diode. A reading of 60 - 120 mA indicates the instrument is functioning properly. A sudden change in current can reflect a problem with the instrument; however, a temporary drop in laser current is normal when anti-icing heaters are initially turned on. If the laser current is weak and the laser begins pulsing, the laser has become overheated. A current reading of zero indicates a failure. A high laser current can indicate the laser is nearing the end of its life.

Laser Power indicates the relative laser power as measured by the laser onboard power monitor. This reading is obtained by converting a digital count to volts, which correlates to the optical power produced by the laser diode. This channel is useful for observing general trends, but currently it does not accurately indicate absolute laser power. However, the channel is still useful in diagnosing laser health. Laser power should stay stable $\pm 20\%$; oscillation beyond this boundary indicates a problem with the laser.

Note that the PIP's laser will most likely be the first instrument component that needs replacement. The laser has a lifetime of approximately 8,000 hours in ideal conditions, but this figure is reduced considerably if there are dramatic thermal variations and electrical oscillations.

More detail on the PIP's housekeeping parameters appears below.

PIP Housekeeping Parameters:

PIP Housekeeping		PIP-DSP Rev B (ABD-0148 RevB)						
Channel	ADC -CH	Use	Input Range	Maximum	Connection	Calibration	units	offset *
1	1--7	Diode 1	0-10 V	4V	Internal	0.004884	Volts/bit	0
2	1--6	Diode64	0-10 V	4V	Internal	0.004884	Volts/bit	0
3	1--5	Diode 32	0-10 V	4V	Internal	0.004884	Volts/bit	0
4	1--4		2-12 V	12 V	J2 Pin 1			0
5	1--3		2-12 V	12 V	J2 pin 3			0
6	1--2		0-10 V	10 V	J2 pin 5			0
7	1--1		0-10 V	5 V	J2 pin 7			0
8	1--0	Board Temp	1.49V @ 25C	5mV/degK	TMP01FP	0.48828	DegC/bit	559
9	0-7		0-10 V	5 V	J4 pin 1			392
10	0-6		0-10 V		J4 pin 3	0	Volts/bit	0
11	0-5		0-10 V		J4 pin 5	0	Volts/bit	0
12	0-4		0-10 V		J4 pin 7	0	Volts/bit	0
13	0-3		0-10 V		J4 pin 9	0	Volts/bit	0
14	0-2		0-10 V		J4 pin 11			2048
15	0-1	Laser Current	0-10 V	2.5V	J4 pin 13	0.122070	mA/bit	0
16	0-0	Laser Power	0-1V		J4 pin 15	0.024414	Volts/bit	0
ADC bits	12							
ADC counts	4096							
ADC range	10							
Volts/bit	0.002441							

* offset may be negative

5.2 Power Problems

The Power Module and the Backplane should be checked first in the event of power problems. The Backplane routes all signals including the power signal between boards, and its connectors must be properly mated and its voltages within required levels. To make sure the Power Module and Backplane are functioning properly, do the following with the probe on:

1. Ensure the five voltage LEDs are lit on the Power Module. This board is mounted on the bottom in the PIP PCB area. Figure 6 shows the 28-V LED, while Figure 7 shows the four LEDs for ± 5 V and ± 15 V. If the 28V LED is unlit, there is no power to the PIP. It will be necessary to trace the power back through the canister and the aircraft. If any of the ± 5 V and ± 15 V LEDs is unlit, there is a DC-to-DC power

supply problem. With the probe power disconnected, reseal the Backplane. If all the LEDs are lit, proceed with the rest of the tests.

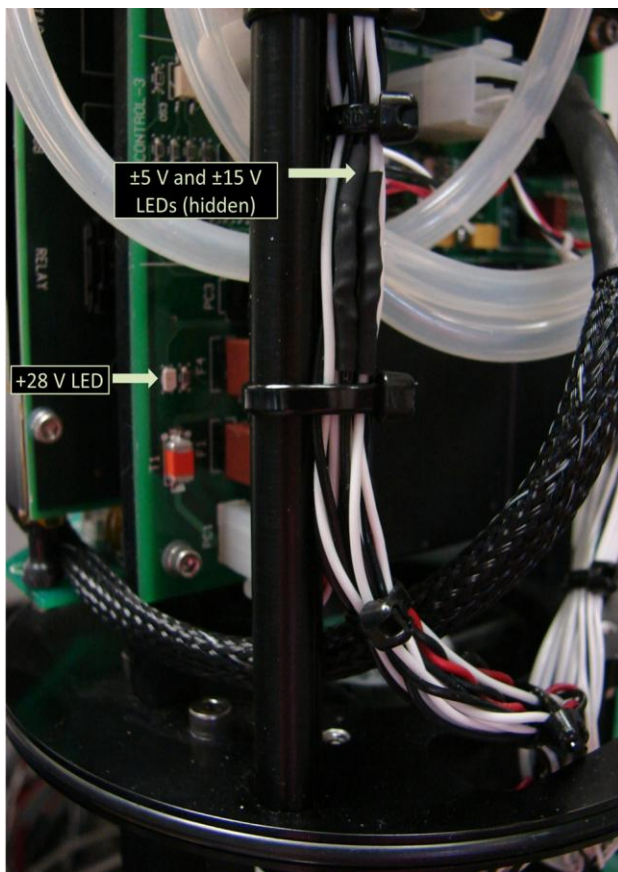


Figure 6: 28-Volt LED

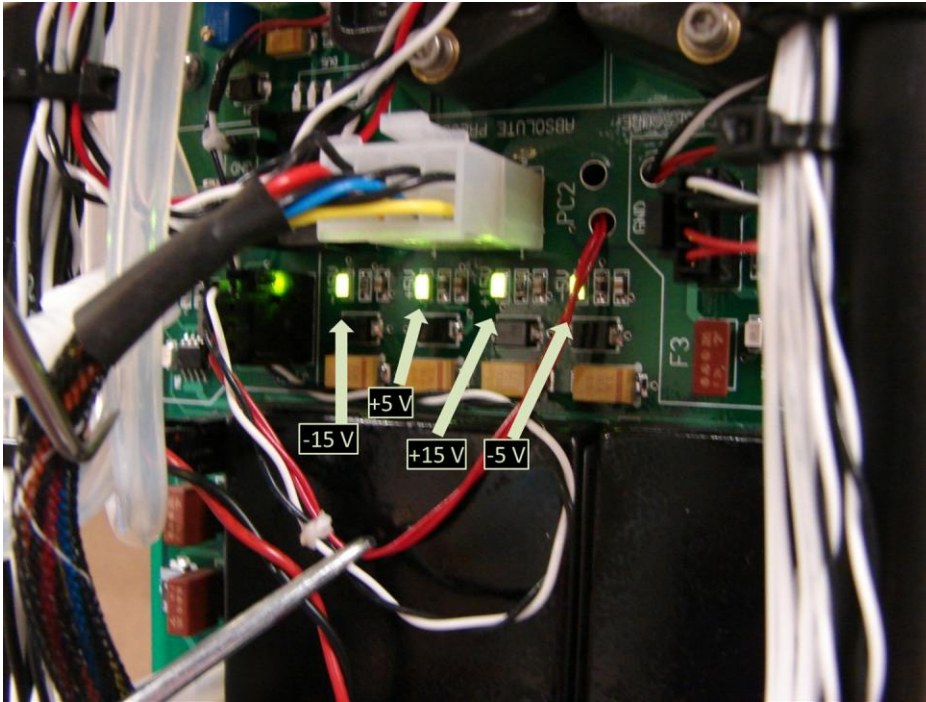


Figure 7: LEDs for ± 5 or ± 15 Voltages

2. Check for +5 Volts on pin one of both the DSP Board and Array connectors (ground is on pin 4 of the DSP Board connector, and 5 of the Array connector). See Figure 8 for details on Backplane pin locations.

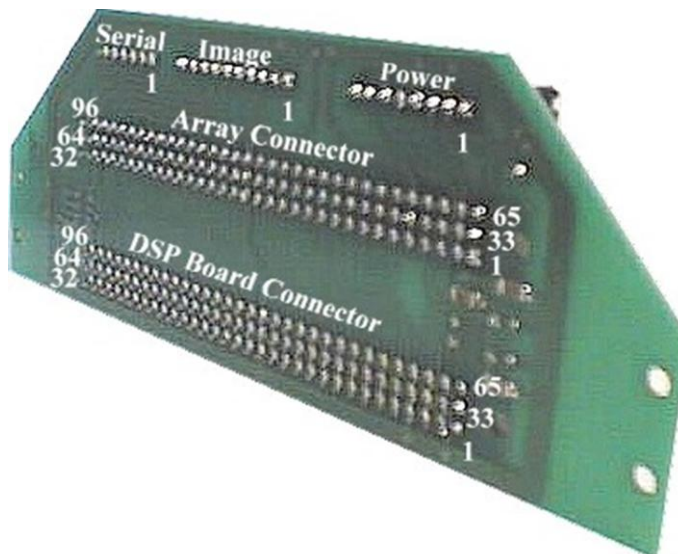


Figure 8: PIP Backplane Board. Note that both the Array and DSP Board Connectors have pin one in the lower right corner. The AMP connectors on the top also have pin one on the right.

3. Check for +15 Volts on pin two of the DSP Board and pin three of the Array connectors.
4. Check for -15 Volts on pin 34 of the DSP Board connector.
5. If any of the voltage levels is bad, check the power connector for the correct levels (+5V on pin 1, ground on 2, -5V on 3, 15V on 5, -15V on 7).

5.3 Image and Data Problems

If the probe is producing no images, the size histogram is empty, or the images consistently have one diode that is always light or dark, there may be a failure on the diode array board. Section 5.3.1 discusses different causes of image problems. Section 5.3.2 provides background information about the diode array that is useful in understanding these issues.

5.3.1 Varieties of Image Problems

If the problem occurring is a pixel that is always “on” in the images, the voltage at the test point (see section 5.3.2) is probably stuck high. Monitor the test point and block the laser from hitting the diode array. If the test point voltage doesn’t drop, there is a problem with the first or second stage amplifier, or the potentiometer has failed. If the test point voltage does drop when the laser is obscured, then the 3rd-stage op amp or the comparator has failed.

If there are no images and/or no sizing histogram data, then a photodiode has probably failed at a low voltage. First check the -Particle signal, which is pin 30 on the Array Connector of the PIP Backplane board. If it is greater than 3V when the laser is not blocked, but falls to less than 2V if the laser is blocked briefly, then the diode array board is not the problem. If the test shows the array board is not working, check the diode test points (see section 5.3.2) with full laser illumination on the diode array. A single test point voltage well below 1V indicates an electrical problem. Contact DMT for further assistance.

5.3.2 Background Information on Diode Array Board

This section provides background information on the diode array board’s signal processing chains. To follow the explanation below, first locate the PIP Diode Array schematic and turn to the page labeled **Diode Array Amplifiers 1, 3, 5, 7**. (Labels

are in the bottom right.) The following discussion pertains to the signal processing chain for diode 7, which is shown at the bottom of the page.

On the array board, there are 64 analog signal-processing circuits just like the one depicted in this signal processing chain. (The PCB is a high-density, 12-layer board, with multiple ground and power planes.) The input marker labeled IN-D is the input from a reverse-biased photodiode. When a particle is imaged, causing a decrease in light on the array, a shadowed photodiode produces a current that flows through R155, the 10K Ω resistor, generating a positive voltage swing on pin 14 of U16 on the order of 1 mV. Amplifier U17D inverts and amplifies this signal, producing a negative swing at its output, viewable at the TP7 test point. Normally, the signal at TP7, with the laser incident on the array, is between 2 and 2.5 Volts; a voltage below 1 under these conditions indicates a problem. When the diode is fully shadowed, the voltage drops to approximately 100 mV. Amplifier U18D DC couples this signal and divides it by $\frac{1}{2}$. Thus comparator U61C will switch from high to low at its output, pin 8 (labeled Diode-D), when shadowing of the laser drops the voltage at TP7 to half its full laser incidence voltage. Note that as the laser is shadowed, the charge stored on capacitor C32 begins to drain off, and the Output of U18D will begin to decay.

The last thing to note on this chain is R129, a potentiometer. This adjusts the DC voltage of TP7. When there is no light on the diode array, the test point is set to approximately 100 mV.

Looking now at the NAND/NOR page of the schematic, note that all 64 of the comparator outputs are ANDed, then ORed together, so that if any one comparator goes low, the -PARTICLE signal goes low. The digital electronics on the DSP board watch this signal to determine when there is a particle and when to begin storing image data. If the signal stays low for more than 100 sample clocks, the electronics stop storing the image until this signal again goes high. *If any one signal chain fails such that its comparator output is stuck low, the PIP will stop measuring particles.*

The DOF comparators perform the same function, but require the DC test point outputs to drop to $\frac{1}{3}$ their nominal voltage before triggering. The digital electronics only use this signal to determine whether the particle should be based on depth of field. The signal does not affect particle image acquisition.

5.4 Contacting DMT regarding PIP Problems

If none of the above trouble-shooting actions resolves the problem with the PIP, contact DMT for assistance. Please be prepared to send a data set that illustrates the problem. If you are using PADS, data files should be in the following format:

- a. All data files from the sampling session should be included with their original names and in their original directory. This includes instrument data files, configuration files, and log files. Image files are optional.
- b. Data files should be the originals that PADS created or unmodified copies of these originals.

6.0 Verifying PIP Calibration with the Spinning Disk Calibrator

The DMT spinning disk calibrator allows users to validate the PIP's size resolution. The calibrator does not fix a faulty optical magnification that sets the size resolution; rather, it is intended solely as a diagnostic.

See *Spinning Disk Calibrator Manual (DOC-0012)* for information on mounting, calibrating, using, and cleaning the spinning disk.

Appendix A: Revisions to Manual

Rev. Date	Rev No.	Summary	Section
4-22-10	G	Updated Schematics	Appendix B
		Updated Calibration section	6.0
10-26-10	H	Removed packing list Inserted mounting instructions	Appendices B and C
1-14-11	I	Updated Diode Voltages	Table 1
6-6-2011	J	Corrected voltage output on TP7 when diode is fully shadowed	5.3.2
4-23-12	K	Removed schematics	Appendix B
		Inserted information on DMT Instrument Locator	Appendix B

Appendix B: DMT Instrument Locator—Operator Guide

Purpose

The Droplet Measurement Technologies (DMT) Instrument Locator tests whether a DMT instrument is responsive to an initialization command. This can be useful in determining if an instrument is powered on and has functional communications lines, or in verifying the serial port number that each instrument is connected to. Beyond this, the software does not ensure that the instrument is functioning properly.

This document describes version 1.0.1 of the Instrument Locator. This version of the program supports the following DMT instruments:

- APSD
- BCP
- CAS and CAS-DPOL
- CDP and CDP-PBP
- CIP and CIP-GS
- CPSD
- FM-100
- FSSP
- MPS
- PCASP-100X
- PCASP-X2
- PIP

Installation

The DMT Instrument Locator is on a USB stick included in a sealed plastic bag. To install the software, follow the instructions on the small card also included in the bag.

Operation

1. To open the Instrument Locator, navigate to `C:\Program Files\PADS 3` and double-click on `DMT Instrument Locator.exe`. You will see the window in Figure 1.

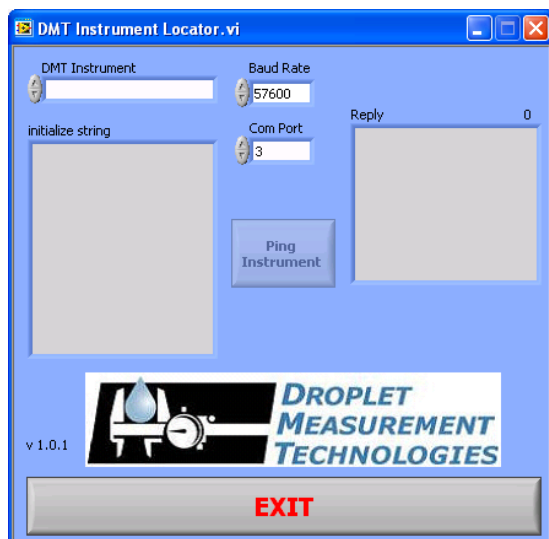


Figure 9: Instrument Locator

2. Click on the **DMT Instrument** field to bring up a list of available instruments. (Grayed-out instruments have not yet been tested with the Instrument Locator.) Select your instrument from the list. The **Baud Rate** will auto-populate, though in some special cases you may need to adjust the baud rate for your specific instrument.
3. Select the COM port for the instrument you want to test.
4. Click on **Ping Instrument**.
5. The Instrument Locator will display the initialization string sent to the instrument and the instrument's reply. All instruments reply with "0606" when sent a valid initialization command. If there is no reply, the Instrument Locator will indicate this with a **No Reply** indicator. The Instrument Locator also displays a possible reason for the communication failure in the **Reply** box.
6. To quit the Instrument Locator, click on **Exit**.

Note: Several DMT instruments—the CDP, CDP-PbP, BCP, FSSP, and FM-100—all respond to the same initialization string. The instrument locator simply sends this string to the instrument. The program has no way of knowing if the instrument connected to the COM port is actually of the correct type. Thus, if you have multiple instruments in your system, it is important to specify the correct COM port for the instrument you wish to test.