USER MANUAL

Mach 6 | 200 kHz Energy Meter and Probes

gentec-eo
PARTNERS for ACCURACY

121-103579

WARRANTY

First Year Warranty

The Gentec-EO MACH 6 Meter carries a one-year warranty (from date of shipment) against material and/or workmanship defects, when used under normal operating conditions. The warranty does not cover damages related to battery leakage or misuse.

Gentec-EO Inc. will repair or replace, at Gentec-EO Inc.'s option, any MACH 6 that proves to be defective during the warranty period, except in the case of product misuse.

Any attempt by an unauthorized person to alter or repair the product voids the warranty.

The manufacturer is not liable for consequential damages of any kind.

Contacting Gentec Electro-Optics Inc.

In case of malfunction, contact your local Gentec-EO distributor or nearest Gentec-EO Inc. office to obtain a return authorization number. The material should be returned to:

Gentec Electro-Optics, Inc.
445, St-Jean-Baptiste, Suite 160
Québec, QC
Canada G2E 5N7

Tel: (418) 651-8003
Fax: (418) 651-1174
E-mail: service@gentec-eo.com
Website: www.gentec-eo.com

CLAIMS

To obtain warranty service, contact your nearest Gentec-EO agent or send the product, with a description of the problem, and prepaid transportation and insurance, to the nearest Gentec-EO agent. Gentec-EO Inc. assumes no risk for damage during transit. Gentec-EO Inc. will, at its option, repair or replace the defective product free of charge or refund your purchase price. However, if Gentec-EO Inc. determines that the failure is caused by misuse, alterations, accident or abnormal conditions of operation or handling, it would therefore not be covered by the warranty.

SAFETY INFORMATION

Do not use the MACH 6 if the device or the detector looks damaged, or if you suspect that the MACH 6 is not operating properly.

Appropriate installation must be done for water-cooled and fan-cooled detectors. Refer to the specific instructions for more information. Wait a few minutes before handling the detectors after power is applied. Surfaces of the detectors get very hot and there is a risk of injury if they are not allowed to cool down.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Caution: Changes or modifications not expressly approved in writing by Gentec-EO Inc. may void the user's authority to operate this equipment.

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1. INTRODUCTION

The MACH 6 is an advanced high speed energy meter capable of measuring up to 200,000 pulses per second. It is used with the MACH 6 Applications Software, which creates a full featured data acquisition system for measuring and displaying laser energy.

The MACH 6 is used with compatible GENTEC-EO probes from the M6-series.

1.1. SPECIFICATIONS

Specifications	MACH 6
Power Supply	9V-15V at 500mA
Dimensions (mm)	167 x 169 x 55
Indicators	Power, Trigger, Buffer Full, Over Temp, Armed, Out of Range
External Trigger	Optically Coupled TTL
External Trigger Slope	Selectable, positive or negative
Internal Trigger	Selectable, 2% to 20% of full scale in 1% increments.
Internal Trigger Accuracy	±10% of the set level.
Trigger Delay	Selectable, 38ns to 3825ns, 15ns increments.
Ranges	Probe Dependent, See probe specifications
Accuracy, Energy Measurement	±1% of full scale Instrument, ±2% of full scale Instrument and Probe
Resolution, Energy Measurement	1 part in 2000
Linearity, Energy Measurement	±1%
Accuracy, PPS Measurement	±1% of reading
Resolution, PPS Measurement	1pps to 10,000pps, < 1Hz 10,000pp to 50,000pps, < 20Hz 50,000pps to 200,000pps, < 80Hz
Input Impedance	10KΩ
Analog Output Full Scale	3.00Vpp
Analog Output Impedance	100Ω
Temperature Compensation Range	15°C to 65°C, User can disable
Wavelength Compensation Range	Probe Dependent, User can disable

1.2. MECHNICAL DESCRIPTION

Figure 1 shows the MACH 6 front panel. Figure 2 shows the MACH 6 back panel.

Figure 1, MACH 6 Front Panel

Figure 2, MACH 6 Back Panel

2. GETTING STARTED

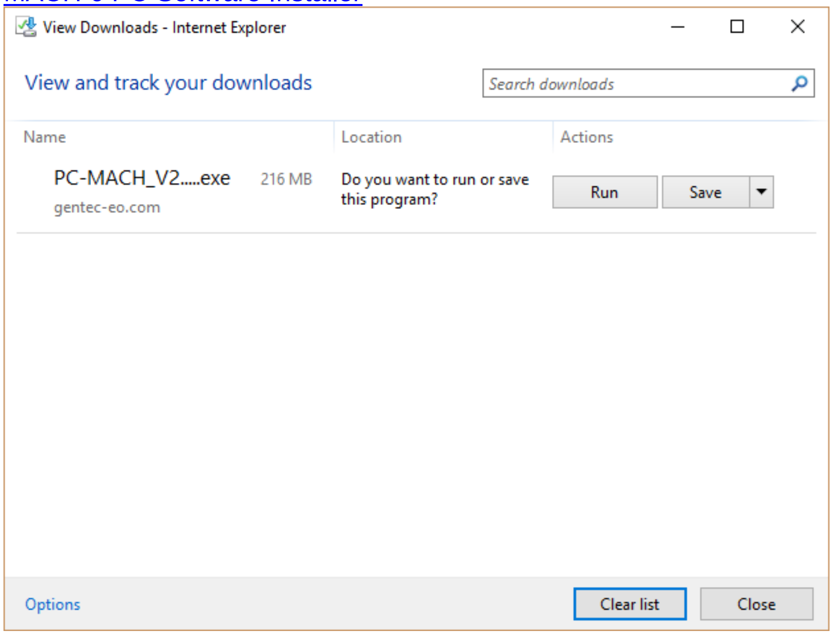
2.1. INSTALLING THE SOFTWARE

Do not plug the MACH 6 into your PC yet.

Step 1, Installing the Applications Software.

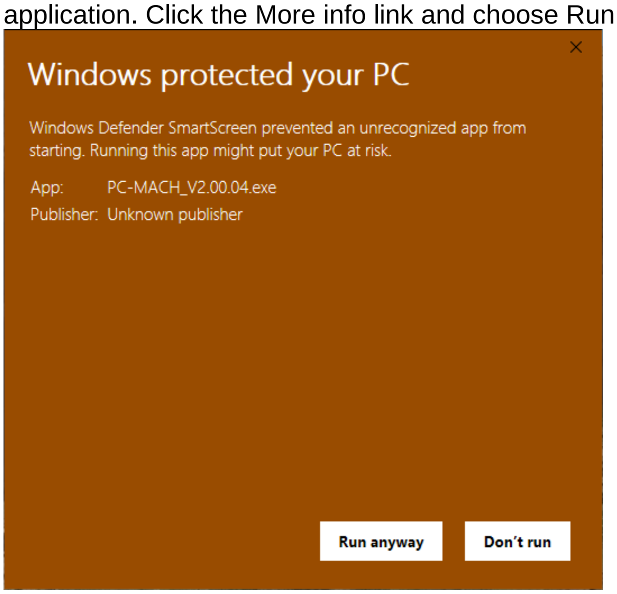
The MACH 6 PC Software is on the Gentec-EO website. Download the installer and run it.

MACH 6 PC Software Installer



Save the file to the location of your choice.

After the file has finished downloading, run the file. Windows may issue a warning that this is an unrecognized application. Click the More info link and choose Run Anyway.



When the User Account control prompt appears, click yes

Step 2, Installing the USB Drivers

The MACH 6 USB drivers are on the Gentec-EO website.

USB Driver Installer

The software installation is now complete. You may now run the application software. The software will wait until it finds a MACH 6 instrument on the USB before it becomes functional. If the MACH 6 is disconnected from the USB or turned off, the software will return to the wait state until the MACH 6 is on the USB again.

2.2. POWER SOURCE

The MACH 6 system is supplied with a 10V, 1.5A universal power module. It will accept voltages from +9V to +15V provided they supply at least 1A and the plug is 5.5mm outer diameter, 2.1 mm inner diameter, and 11mm in length, with the center being positive. Plug the supply into the DC power jack located on the front panel.

2.3. PROBE CONNECTION

The MACH 6 probes use a 7 pin locking connector. See figure 2. Plug in the probe by lining up the red reference dots and pushing the connector until it latches into its locked position. To remove the probe, power down the unit and pull on the outer sleeve. The connector will unlock and disengage.

2.4. INDICATOR LEDS

There are 6 LEDs on the MACH 6 front panel as shown in figure 1.

The Power LED is illuminated whenever an external supply is plugged into the DC power jack.

The Trigger LED illuminated when the MACH 6 is triggered. This LED functions at all times, whether the MACH 6 is armed or not.

The Over temp LED illuminates when the measure probe temperature exceeds 65°C. This LED is only updated when the unit is armed and triggered.

The Armed LED illuminated when the unit has been armed for data collection. Note that the unit can be armed even if no triggers are present.

The Out of Range LED illuminates when the internal ADC detects a voltage outside of its measurement range. This LED is only updated when the unit is armed and triggered.

The Buffer Full LED illuminates when the internal pulse memory is full.

2.5. USB

The MACH 6 communicates with the host PC via a USB port. The device supports full speed USB 2.0. The host PC must have the MACH 6 USB drivers installed. These drivers are on the Gentec-eo website. The Application Software is written in LabVIEW and uses the NI-VISA software from National Instruments to affect a communication link with the MACH 6. The USB cable can be unplugged form the MACH 6 during operation at any time, but the applications software will not function in this state other than to wait for a MACH 6 to be connected to the USB.

2.6. DETECTOR OUTPUT

The Detector Output provides an amplified, buffered signal from the probe. The full scale signal is 3.00V in a given range and is offset by -1.25V nominal.

2.7. EXTERNAL TRIGGER

MACH 6 supports internal and external triggering. Connect a TTL trigger signal to this input to use external triggering.

2.8. TURNING THE UNIT ON

Before turning the MACH 6 on, be sure that the probe in use is plugged in. When the MACH 6 powers up, it reads the probe memory to obtain required information for correct operation. MACH 6 cannot detect a probe removal, so hot swapping the probe is not permitted. Doing so will not cause damage, but the probe information will not be updated. Once the probe and power supply are connected, turn the unit on by setting the Power Switch to ON. The Power LED will illuminate. The remaining LEDs will turn on briefly as the MACH 6 performs internal self-tests, then they will turn off. The MACH 6 is now ready to use.

2.9. POWER ON TESTS

When powered on, the MACH 6 tests its internal memory and its control circuitry to ensure it can accurately measure data. If the internal memory fails its test, the MACH 6 will flash the Over Temp LED. If the control circuitry fails its test, the MACH 6 will flash the Out of Range LED. Should either of these conditions occur, contact GENTEC-EO for service of the unit.

3. APPLICATION SOFTWARE

The MACH 6 Application Software consists of controls and indicators on 6 display tabs:

1. The Instrument Controls Display.
2. The Strip Chart Display.
3. The Histogram Display.
4. The Statistics Display.
5. The FFT Display.
6. The Probe Data Display

The desired display is selected by clicking on the appropriate tab.

3.1. THE MAIN CONTROLS

Figure 3 shows the Instrument Controls Display of the Applications Software.

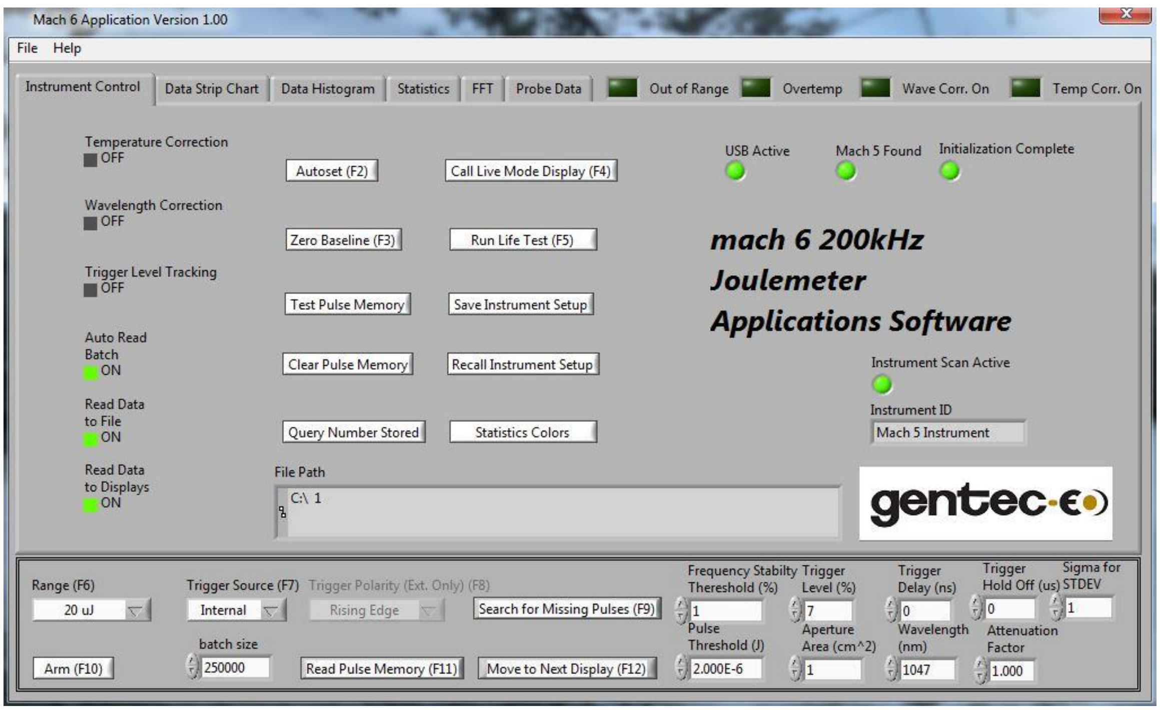


Figure 3, Instrument Controls Display

The main controls for the instrument are below the display tabs. They are:

Range

Sets the instrument to the desired range. Note that the available ranges are dependant on the sensor responsivity. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges. If this occurs, the instrument will set itself to the same currently set range if it is still available. If it is not, the instrument will set itself to the next available range.

Trigger Level

The trigger level in percent of full scale. If the level is set to 10% and the range is set to 200uJ, then the instrument will trigger on signals greater than 20uJ.

Trigger Source

Internal causes the instrument to take a measurement (if it is armed) whenever a pulse is present that is greater than the set trigger level.

External causes the instrument to take a measurement (if it is armed) whenever an external trigger pulse is sent, regardless of whether or not a laser pulse has occurred. This is useful for testing for missing laser pulses.

Trigger Polarity

Sets the trigger edge polarity for the external trigger pulse. Positive triggers on the rising edge of the trigger pulse, negative triggers on the falling edge of the trigger pulse.

Trigger Delay

This is the delay of the trigger pulse. If used with external trigger, the timing relationship between the external trigger pulse and the laser firing event can be accounted for by setting the delay appropriately. The range is -938ns to +2480ns.

Trigger Hold off

This is the hold off in microseconds for the trigger event. After a trigger event the instrument will not trigger again until the hold off expires. This is useful for bursts of pulses at a given rep rate. Supposed there are bursts of 5 pulses occurring every 10us and the bursts themselves occur every 200us. Setting to hold off to 50us will cause only the first pulse in the 5 pulse burst to be measured.

Setting the trigger hold off to zero disables trigger hold off.

Arm

Arms the instrument for a data gathering run. Arming the instrument clears any existing data from the pulse memory, and then enables trigger detection in the processor. As each pulse is measured, the result is stored in pulse memory, up to 4 million pulses. (4,194,304) When the pulse memory is full, measurement continues but the data is discarded. Note that arming the instrument disables all other controls on the application that communicate with the instrument. This is done to prevent the instrument from losing pulse data while responding to commands or queries.

Read Pulse Memory

This control calls a user prompt that asks for the pulse offset and the number of pulses to retrieve from pulse storage memory. Once that information is acquired, the pulse memory is read. The destination of the pulse memory is dependant on the state of the Read to File and Read to Display check boxes.

The pulse memory is capable of storing up to 4,194,303 pulses. This is a large volume of data and it can be time consuming to retrieve all of it at once. The pulse offset and number of pulses to retrieve controls make this manageable. As an example, suppose there are 2 million pulses in the memory. The user can ask for this data in batches of 500,000 pulses at a time in 4 batches:

Read 1, pulse offset = 1, number of pulses to retrieve = 500,000
Read 2, pulse offset = 500,001, number of pulses to retrieve = 500,000
Read 3, pulse offset = 1,000,001, number of pulses to retrieve = 500,000

Read 4, pulse offset = 1,500,001, number of pulses to retrieve = 500,000

The response of the application to large pulse batches will depend on the host PC. A test MACHine with a 2.66GHz dual core processor and 3GB of memory retrieved 500,000 pulses to a data file in 7.9 seconds. The retrieval to the display took 20.9 seconds. The extra time is due to the processing of the large data arrays in the application.

Batch Size

The number of pulses to measure when the instrument is armed.

Missing Pulse Threshold

The energy level used to test a data set for missing pulses. Any pulse energy in the set that is lower than this threshold will cause a missing pulse to be recorded. This control must be set before testing the data.

% Frequency Stability Threshold

With internal triggering, if the pulse is below the trigger level, no trigger will occur, but the period timer will still be running. This means that the period will be longer between the pulses adjacent to the missing pulses. The applications software examines the pulse data for this condition and records the time stamps where the period is discontinuous. From the continuous period data, the true period can be found and used to count how many pulses were missing in the discontinuities.

The % Frequency Stability Threshold setting determines how much time stamp mismatch is allowed before a pulse is determined to be missing.

This control must be set before the data set is tested.

Search Data For Missing Pulses

Searches the current data set for missing pulses. Pulse data are searched using to criteria, the Missing Pulse Threshold and the Frequency Stability Threshold.

A large data set can take many seconds to search.

Missing Pulse Threshold

The energy level used to test a data set for missing pulses. Any pulse energy in the set that is lower than this threshold will cause a missing pulse to be recorded.

Frequency Stability Threshold

With internal triggering, if the pulse is below the trigger level, no trigger will occur, but the period timer will still be running. This means that the period will be longer between the pulses adjacent to the missing pulses. The applications software examines the pulse data for this condition and records the time stamps where the period is discontinuous. From the continuous period data, the true period can be found and used to count how many pulses were missing in the discontinuities.

The % Frequency Stability Threshold setting determines how much time stamp mismatch is allowed when computing the true frequency.

Wavelength

Sets the wavelength of the laser in use. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on with the wavelength set to any value other than the calibration wavelength may cause a rescale of the available ranges. If this occurs, the instrument will set itself to the same currently set range if it is still available. If it is not, the instrument will set itself to the next available range.

Aperture Area

The sensor or user aperture area in cm^2.

Attenuation Factor

This is used to compensate the data for the use of an external optic, such as a beam splitter. If the external optic is only presenting 10% of the beam to the sensor, then enter 0.1 for the factor. The data will be scaled by 1 / Attenuation Factor so that it represents the energy of the beam before the optic.

If this causes the data values to exceed the range, then the strip charts in the various displays will need to be set to auto scale before the data will be visible.

Note: This parameter must be set before reading the Pulse Data.

Sigma for Standard Deviation

The number, z, used in the standard deviation value. If a data distribution is approximately normal then about 68% of the values are within 1 standard deviation of the mean, about 95% of the values are within two standard deviations and about 99.7% lie within 3 standard deviations.

For various values of z, the percentage of values expected to lie in the symmetric confidence interval (-zs,zs) are as follows:

s	percentage
1s	68.27%
2s	95.450%
3s	99.7300%
4s	99.993666%
5s	99.99994267%
6s	99.9999998027%

Move to Next Display

Moves the Tab Control to the next Display Tab.

There are four LED indicators for the instrument above the display tabs. They are:

> The Over temp LED illuminates when the measure probe temperature exceeds 65°C. This LED is only updated when the unit is armed and triggered.
>
> The Out of Range LED illuminates when the internal ADC detects a voltage outside of its measurement range. This LED is only updated when the unit is armed and triggered.
>
> The Wavelength Correction On LED illuminates if Wavelength Correction is On.
>
> The Temperature Correction On LED illuminates if Temperature Correction is On.

The Instrument Control Display Tab also shown in figure 3 is used to control instrument settings that are not as frequently used as those on the Main Display The display contains controls and indicators.

3.2. THE INSTRUMENT CONTROL DISPLAY

The Controls on the Instrument Control Display area are:

Temperature Correction

Turns Temperature Compensation On. The instrument measures the temperature of the sensor and records the data with each pulse. If Temperature Compensation is On, this data is used to compensate the measured pulse data for temperature induced responsivity changes. If Temperature Compensation is Off, the data is not corrected. The instrument always sends the temperature data with the pulse data. Compensation is done by the host application.

Wavelength Correction

Turns Wavelength Compensation On. The sensor responsivity is wavelength dependant. Turning Wavelength Compensation On causes the instrument to restructure its internal gains to compensate for the variation in responsivity. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges. If this occurs, the instrument will set itself to the same currently set range if it is still available. If it is not, the instrument will set itself to the next available range.

Trigger Level Tracking

Turns Trigger Level Tracking On. This applies to Internal Trigger Mode only.

Since the MACH 6 uses a hardware trigger, and the pulse that creates the trigger exhibits a DC drift proportional to average power, the trigger level will appear to shift in relation to the pulse as the. At low duty cycle, the pulse baseline will be stable and triggers will occur as intended. With high duty cycles the pulse will drift negative. If this drift is greater than the set trigger level the instrument will stop triggering and miss pulses. To prevent this, the trigger level must be corrected as the pulse baseline drifts. Trigger Tracking monitors the DC level of the pulse and modifies the trigger level so it remains at the set level in relation to the pulse. When triggering stops or MACH 6 is disarmed, or trigger tracking is turned off, the trigger level returns to its unmodified state.

Test Pulse Memory

Tests the internal instrument pulse storage memory and returns the result. Note that testing the pulse storage memory is destructive of any pulse data currently stored.

Clear Pulse Memory

Clears the internal instrument pulse storage memory. Note that clearing the pulse storage memory is destructive of any pulse data currently stored.

Query Number Stored

Returns the number of pulses currently stored in the pulse memory.

Auto Read Batch

If this box is checked, then after a data batch is taken it will be automatically directed to a data file, to the displays, or both depending on the state of the Read to File and Read to Displays check boxes.

If there is no currently open data file, you will be prompted to select one. Subsequent files will be auto incremented.

Read to File

Sets the target for any pulses read from instrument memory to a text file. If a data file is currently open then it will be used. If there is no file open, the user will be prompted to select or create a file. Data is stored in the following format:

Pulse Energy (in Joules), Time Stamp (in Seconds), Probe Temperature (in degrees Celsius), and Error Flag

The Error flag is decoded as follows:

0 = no errors in batch.
1 = out of range error for one or more pulses in batch.
2 = over temp error for one or more pulses in batch.
3 = out of range and over temp errors for one or more pulses in batch.

Read to Display

Sets the target for any pulses read from instrument memory to the application displays. (Strip Chart, Histogram, FFT, and Statistics pages)

Autoset

Calls the Autoset VI. This VI attempts to find the best range and trigger level for the signal being measured. The flow is:

1. Set the trigger source to internal.
2. Set the trigger delay to 0ns.
3. Set trigger level to 7%
4. Set Range to top Range.
5. Test for triggering.

If no triggers are present, the VI reduces the range to the next lowest and tests for triggering. It repeats this process until the lowest range is reached. If no triggers are present, it then reduces the trigger level 1% at a time until either triggering occurs or the minimum trigger level is reached.

When a trigger is found, the VI returns the discovered setup to the Instrument Controls Display.

Zero Baseline

The DC level of a pulse for a Pyroelectric sensor is dependant on the average energy. If the DC level drifts out of range, pressing this button will cause the instrument to readjust the DC level in the instrument to compensate for this drift.

3.3. THE LIVE MODE DISPLAY

Call Live Mode Display

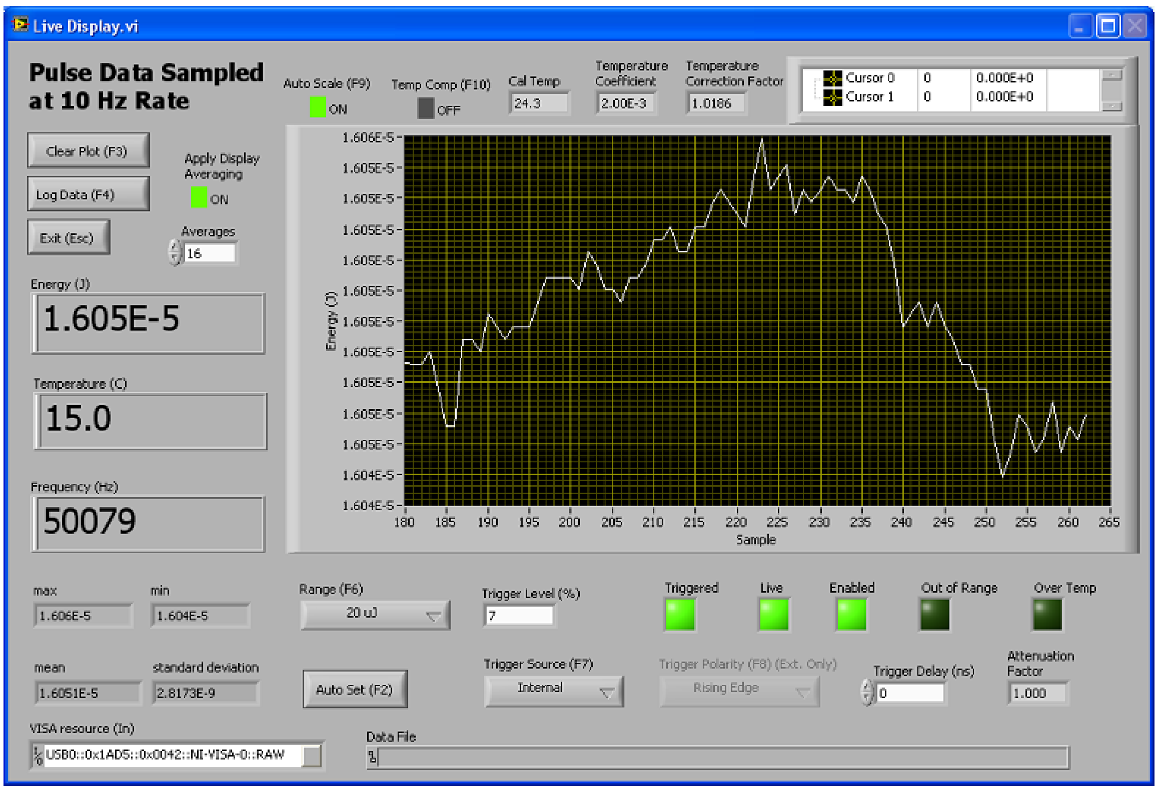
Calls a display of measured data sampled at a 10Hz rate. Calling the display side affects:

Range, Trigger Level, Trigger Source, Trigger Polarity, and Trigger Delay

as these parameters are controllable from the Live Mode Display VI. The data may be logged to a file for later analysis. Note that the statistics displayed are being performed on the data set. To reset and start a new batch of statistics, press the Clear Plot button. The display averaging is a moving average. This means that the average will not be complete until all the samples are taken, but the displays will reflect the current averaged value until this happens. Suppose that a batch size of 5 is selected, and then Apply Display Averaging is selected. The samples will be averaged as follows:

Sample Number	**Number Averaged**
1	1 sample summed, divided by 1
2	2 samples summed, divided by 2
3	3 samples summed, divided by 3
4	4 samples summed, divided by 4
5	5 samples summed, divided by 5

The averaging filter is now full. As each new sample is taken, it will replace the oldest sample and a new average will be computed based on the new data set, that is sample 6 will replace sample 1, the and the new set will be averaged.



3.4. THE LIFE TEST DISPLAY

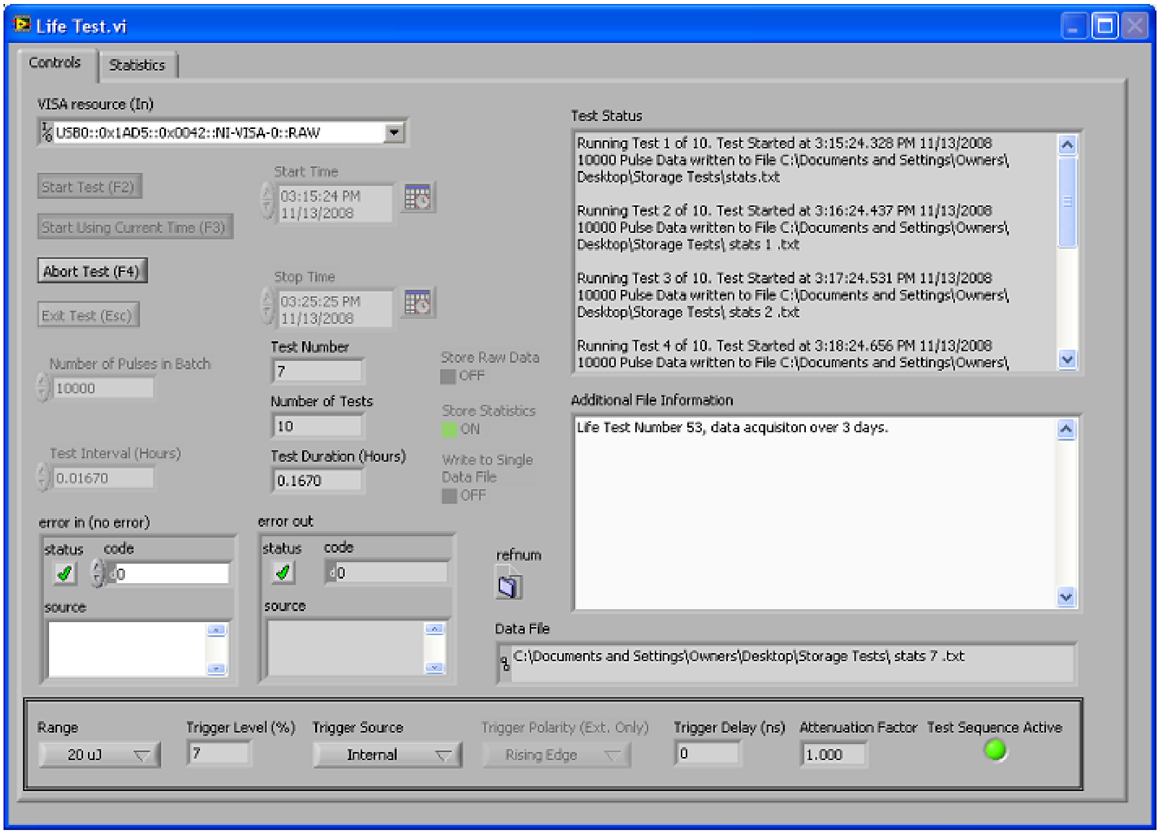
Run Life Test

The Life Tests Vi will start a test at a desired time; measure the desired number of pulses at a desired interval, until the desired stop time is reached. Each test in the sequence is stored in an auto incrementing file. Each test sets min, mean, and max is plotted on a strip chart for quick reference. When the test is started, it will prompt for a file name. That file name will be used for all tests in the sequence, with a number appended to it to differentiate the data sets. For example, if you name the file My Test Set, and there are 5 tests in the set, the saved files will be My Test Set 1.txt, My Test Set 2.txt, My Test Set 3.txt, My Test Set 4.txt, and My Test Set 5.txt.

There are two methods of running a life test. You can type in a Start Time, Stop Time, Number of Pulses in Batch, and a Test Interval. When Start Test is pressed, the VI will calculate the number of tests and the test duration. It will then wait until the selected start time to begin the test sequence. Alternatively, you can type in Number of

Pulses in Batch and a Test Interval, and then press Start Using Current Time. The VI will prompt for the number of tests to run, and then it will calculate the Stop Time and the Test Duration and begin testing immediately.

Test data may be viewed in the main application the same as any saved data set, unless you have appended additional test to the file by typing into the Additional File Information text box.



The Controls are:

Start Test

Starts the test with the selected parameters for Start Time, Stop Time, and Test Interval.

Start Using Current Time

Starts the test immediately and calculates the Stop Time from the Current Time, Number of Tests, and Test Interval.

Abort Test

Aborts the currently running test sequence. Any test files that have been taken prior to the abort will be saved.

Exit Test

Exits the Life test VI and returns to the main application.

Number of Pulses in Batch

The Number of pulses to measure when the instrument is armed. The measured pulse batch data will be written to the test file. Note that the first pulse in the batch after an arm is always discarded by the MACH 6. (See the Measuring Data Section) If the laser is free running, this will not be an issue. If the laser is in burst mode, then be sure to set the batch size to 1 less than the burst size.

Test Interval

How often to measure a batch. For example, you can set up the VI to start at 12:00 AM, stop at 8:00 AM, and measure a batch every hour. The VI will measure the batch size set at 12:00 AM, 1:00 AM, 2:00 AM, 3:00 AM, 4:00 AM, 5:00 AM, 6:00 AM, and 7:00 AM.

Be sure that you have made a reasonable setup. If you have a test interval of a few seconds, the individual tests will not have time to run before the next test is called. Note that in this case the tests will still run in the proper sequence and will be executed as fast as possible.

Start Time

When to start the first test. Must be less than Stop Time and greater than the current time.

Stop Time

When to stop the last test. Must be greater than Start Time and greater than the current time.

Additional File Information

Enter notes and other information you wish to be appended to each of the test files in the set. This information can be updated in between tests, but do not update this while a test is active.

Store Raw Data

Store the raw pulse data. Each pulse will be stored, with its time stamp, its temperature, and the error flag.

Store Statistics

If this box is checked then statistics on each batch will be stored in the data file(s). The stored values are selected by the user. When this box is checked, the following Stats Selection Menu will appear:

The selected stats will be stored, comma separated. The last value stored will always be the Error Flags for the data set.

An error flag is decoded as follows:

0 = no errors in batch.
1 = out of range error for one or more pulses in batch.
2 = over temp error for one or more pulses in batch.

3 = out of range and over temp errors for one or more pulses in batch.

Write to Single File

If this box is checked then data will be written to a single file rather than an auto incremented series of files. This is useful when small results files are expected, as is the case with small batches or storing statistics only. Each set of test data will be appended to the file, and the Additional file information will be placed at the end of the complete file.

Addition File Information

Every data file will also contain the date, time, **Additional File Information,** and the state of the MACH 6 when the data was taken.

The Indicators are:

Test Number

The currently running test or the last ran test.

Number of Tests

The number of tests that will be ran. This number is:

Test Duration / Test Interval rounded to the next highest integer.

Test Duration

The elapsed time from Start Time to Stop Time, in hours.

Test Status

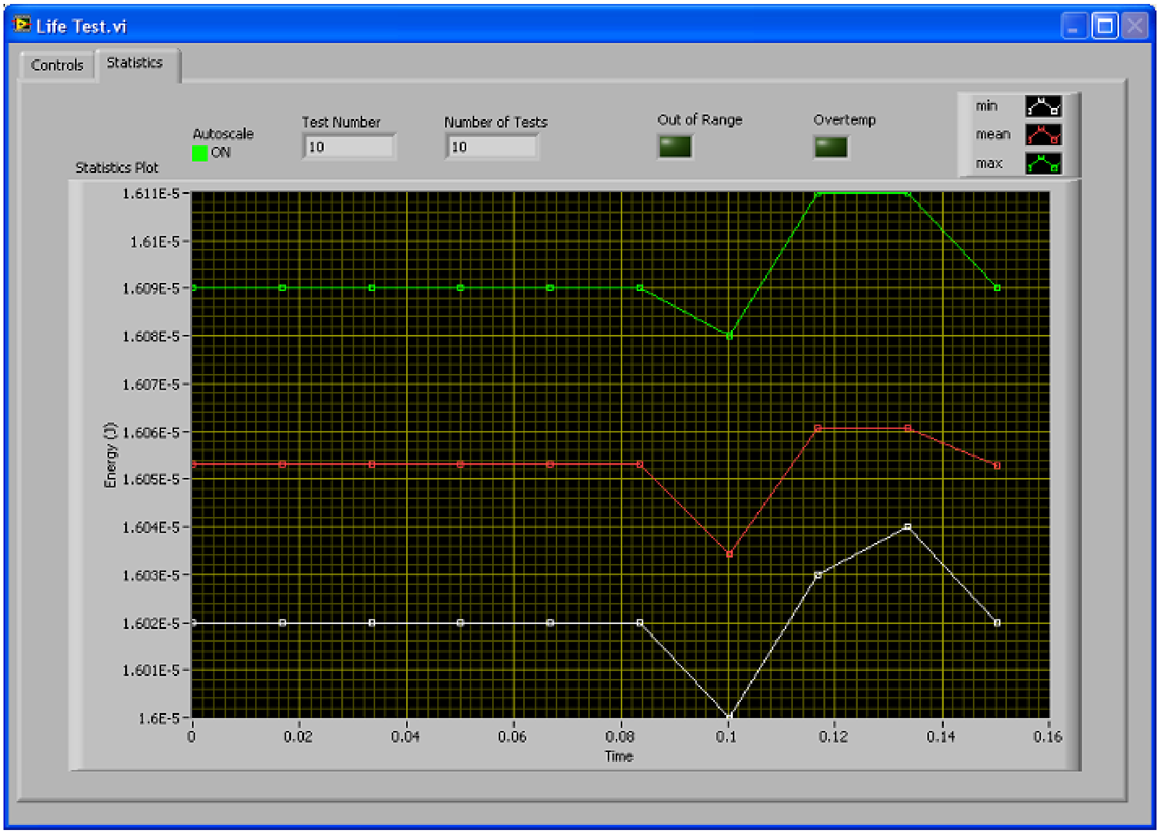
The current status of the running test sequence.

Data File

The last data file that was written to.

Statistics Strip Chart

A running display of the data sets statistics, as well as any error conditions in the current data set. The chart may be auto scaled, but the auto scale will not occur until a new data set is plotted.



Also included are the range and trigger status of the instrument during the test. These parameters cannot be changed during a life test.

Save Instrument Setup

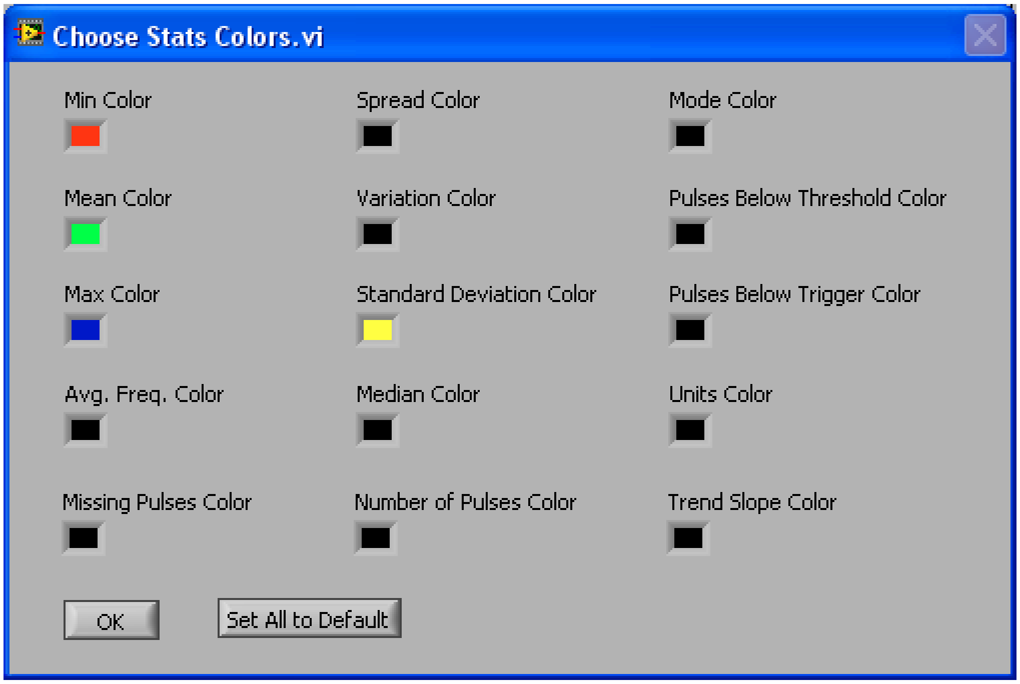
Saves the current instrument settings for recall.

Recall Instrument Setup

Recalls a saved instrument setup.

Statistics Colors

Calls a VI that allows custom colors to be set for the Statistics indicators. These colors are persistent until changed by the user.



File Path

The path and name of the currently open data file.

USB Active

Illuminates whenever the application detects a MACH 6 instrument has been plugged into the USB.

MACH 6 Found

Whenever the application detects a MACH 6 instrument has been plugged into the USB, it queries it for its identification. If the response is correct, this LED illuminates.

Initialization Complete

Whenever the application detects a MACH 6 instrument has been plugged into the USB, it initializes the GUI and the instrument based on the instrument setup and the probe in use. When the initialization is complete, this LED illuminates.

3.5. THE APPLICATIONS SOFTWARE MENU

Menu Items

There are 2 menus on the applications software, File, and Help.

The File Menu has 5sub items: Open Data File, Copy Data File to Displays, Copy Display Data to File, Close Data File, and Exit.

Open Data file opens a saved data file. The file path will be displayed in the file path indicator.

Copy Data File to Displays copies the contents of the currently open data file to the application displays.

Copy Display Data to File copies the currently displayed data to a data file. The user will be prompted to choose the destination file.

Close Data file closes the currently open data file. The file path will be removed from the file path indicator.

Exit stops the application and exits the program. Any open files are closed.

The Help Menu has 3 sub items: Show Context Help, Help, and About.

Show Context Help turns on context sensitive help. Placing the mouse cursor over an item on the GUI will cause a help window to appear for that item if this control is On. Setting the control to Off closes the help window.

Call Help File calls a Compiled Help File.

About calls information about the software.

3.6. THE STRIP CHART DISPLAY

Figure 4 shows the Strip Chart Display of the Applications Software.

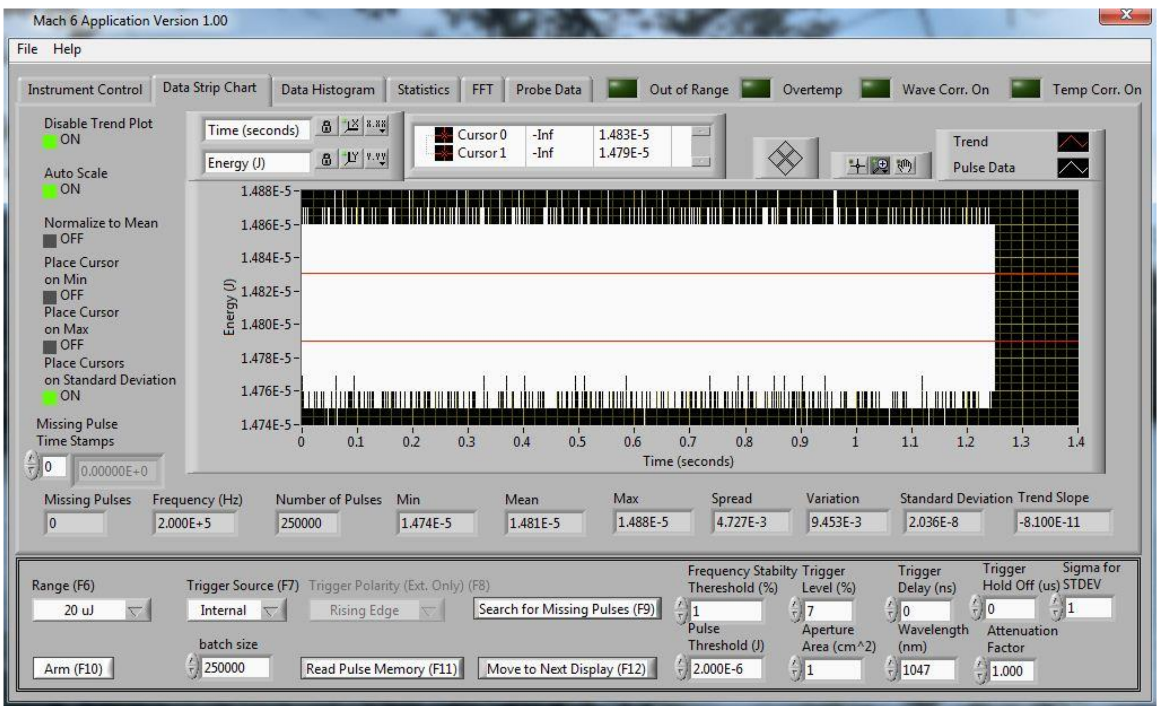


Figure 4, Strip Chart Display

The functions of the controls or indicators are:

Energy Plot

A strip chart of the retrieved data set, if the target has been set to display, or if a data file has been copied into the displays. The trend (slope) of the data is also plotted.

Variation

Variation is defined as (Max - Min) / Mean.

Trend Slope

The slope of the data trend line.

Auto Scale

Auto Scales the Y axis of the strip chart.

Normalize to Mean

Plots the data as data / mean.

Place Cursor on Min

Places a cursor on the minimum value and its time stamp on the strip chart.

Place Cursor on Max

Places a cursor on the maximum value and its time stamp on the strip chart.

Place Cursors on Standard Deviation

Places cursors on the Standard Deviation, plus and minus, from the mean on the strip chart

Missing Pulse Time Stamps

With internal triggering, if the pulse is below the trigger level, no trigger will occur, but the period timer will still be running. This means that the period will be longer between the pulses adjacent to the missing pulses. The applications software examines the pulse data for this condition and records the time stamps where the period is discontinuous. From the continuous period data, the true period can be found and used to count how many pulses were missing in the discontinuities.

Frequency

The measured average frequency of the data set. Each pulse has a time stamp. The number of pulses, divided by the sum of all time stamps is the average frequency.

Number of Pulses

The number of pulses in the data set.

Missing Pulses

The number of missing pulses in the data set. A missing pulse is defined to be a pulse with energy less than the user set threshold level. This feature works with both internal and external triggering. The method of finding missing pulses is different depending on why the pulse is missed.

With external triggering, if a trigger event occurs a measurement will be taken even if no pulse or a runt pulse is present. This will cause a missing trigger to be recorded.

With internal triggering, if the pulse is below the trigger level, no trigger will occur, but the period timer will still be running. This means that the period will be longer between the pulses adjacent to the missing pulses. The applications software examines the pulse data for this condition and records the time stamps where the period is discontinuous. From the continuous period data, the true period can be found and used to count how many pulses were missing in the discontinuities.

Min

The minimum pulse energy in the data set.

Max

The maximum pulse energy in the data set.

Mean

The mean pulse energy in the data set.

Spread

Spread is defined as:

(max - min) / (max + min)

Standard Deviation

The standard deviation of the pulse energy in the data set. This can be interpreted as the RMS noise. Standard Deviation and Variance Details:

The VI calculates the output values using the following equations.

$$\mu = \sum_{i=0}^{n-1} \left[X_i / n \right]$$

where µ is mean and n is the number of elements in X.

standard deviation = Q^2

$$Q^2 = \sum_{i=0}^{n-1} \left[(X_i - \mu)^2 / (n - 1) \right]$$

where Q is variance, µ is mean.

3.7. THE HISTOGRAM DISPLAY

Figure 5 shows the Histogram Display of the Applications Software.

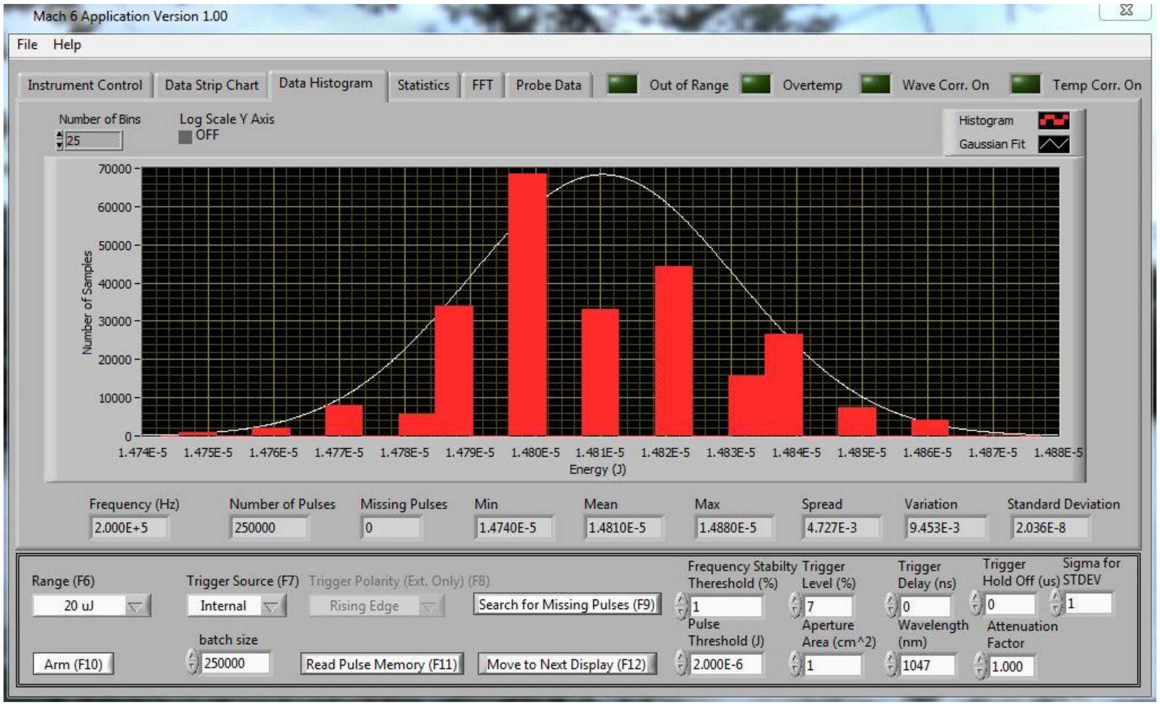


Figure 5, Histogram Display

The functions of the controls or indicators are:

Number of Bins

Number of bins to be used to calculate the histogram.

Histogram Plot

Histogram of the measured pulse energies in the sample buffer. The Gaussian fit to the data is plotted as well.

The statistics are shown on this display as well. See the Strip Chart section for their description.

3.8. THE STATISTICS DISPLAY

Figure 6 shows the Statistics Display of the Applications Software.

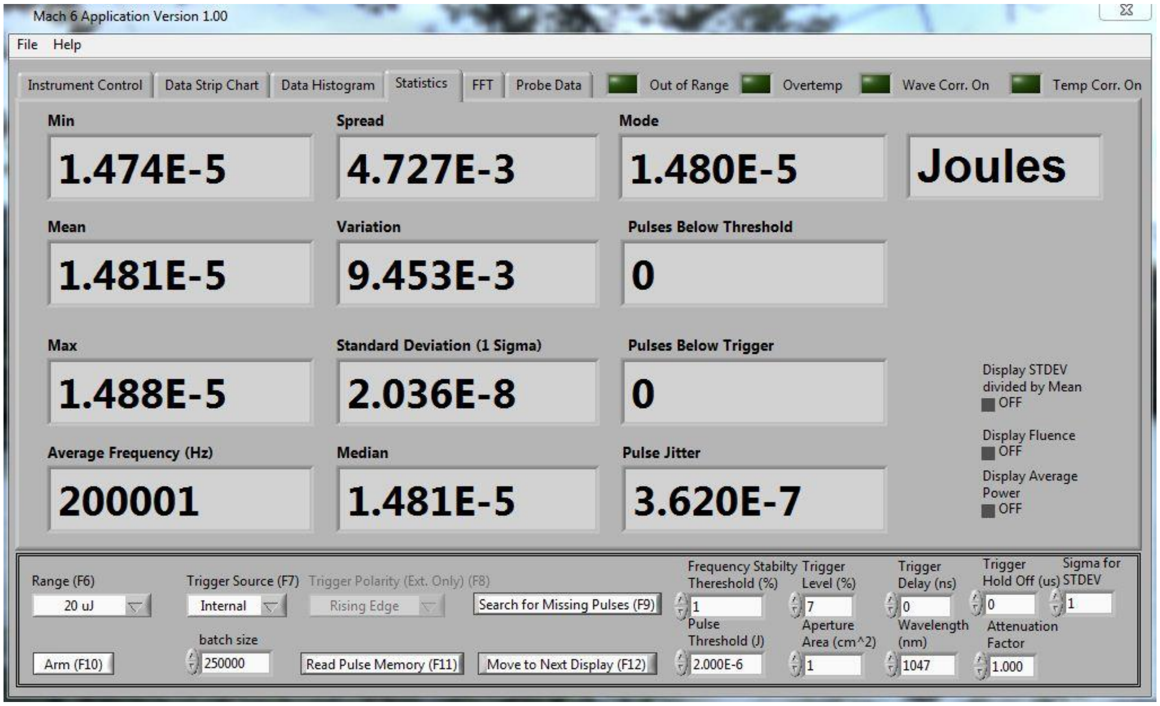


Figure 6, Statistics Display

The functions of the controls or indicators are:

Display STDEV Divided by Mean

Displays the standard deviation as:

Standard Deviation / Mean

Display Fluence

Displays the statistics as Fluence, J/cm^2.

Display Average Power

Displays the statistics as Average Power. This is calculated as Watts = Joules x Frequency.

Min

The minimum pulse energy in the data set.

Max

The maximum pulse energy in the data set.

Mean

The mean pulse energy in the data set.

Spread

Spread is defined as:

(max - min) / (max + min)

Median

Finds the median value of the pulse energy data by sorting the values of pulse energy and selecting the middle element(s) of the sorted array.

Standard Deviation

The standard deviation of the pulse energy in the data set. This can be interpreted as the RMS noise. Standard Deviation and Variance Details:

The VI calculates the output values using the following equations.

$$\mu = \sum_{i=0}^{n-1} [X_i / n]$$

Where µ is mean and n is the number of elements in X.

Standard deviation = Q^2

$$Q^2 = \sum_{i=0}^{n-1} [(X_i - \mu)^2 / (n - 1)]$$

Where Q is variance, µ is mean.

Mode

Mode is the most frequently occurring value in a sequence of numbers. For example, if the input sequence is

X = {0, 1, 3, 3, 4, 4, 4, 5, 5, 7},

the mode of X is 4 because that is the value that most often occurs in X.

Pulses Below Threshold

When the Search Data for Missing Pulses button is pressed, the current data set is examined. Any pulses with energy less than the threshold are flagged as missing, and their time stamps are recorded and displayed. This can be used with internal and external triggering, but it is most effective when used with external triggering.

Pulses Below Trigger

With internal triggering, if the pulse is below the trigger level, no trigger will occur, but the period timer will still be running. This means that the period will be longer between the pulses adjacent to the missing pulses. The applications software examines the pulse data for this condition and records the time stamps where the period is discontinuous. From the continuous period data, the true period can be found and used to count how many pulses were missing in the discontinuities.

Average Frequency

The measured average frequency of the data set.

Pulse Jitter

The difference between the maximum and minimum pulse periods in the data set.

3.9. THE FFT DISPLAY

Figure 7 shows the FFT Display of the Applications Software. This is useful for finding periodic disturbances in the data. The plot shown was taken with an 11 kHz AM modulation applied to the 50 kHz pulse signal. The 11 kHz modulation is clearly seen.

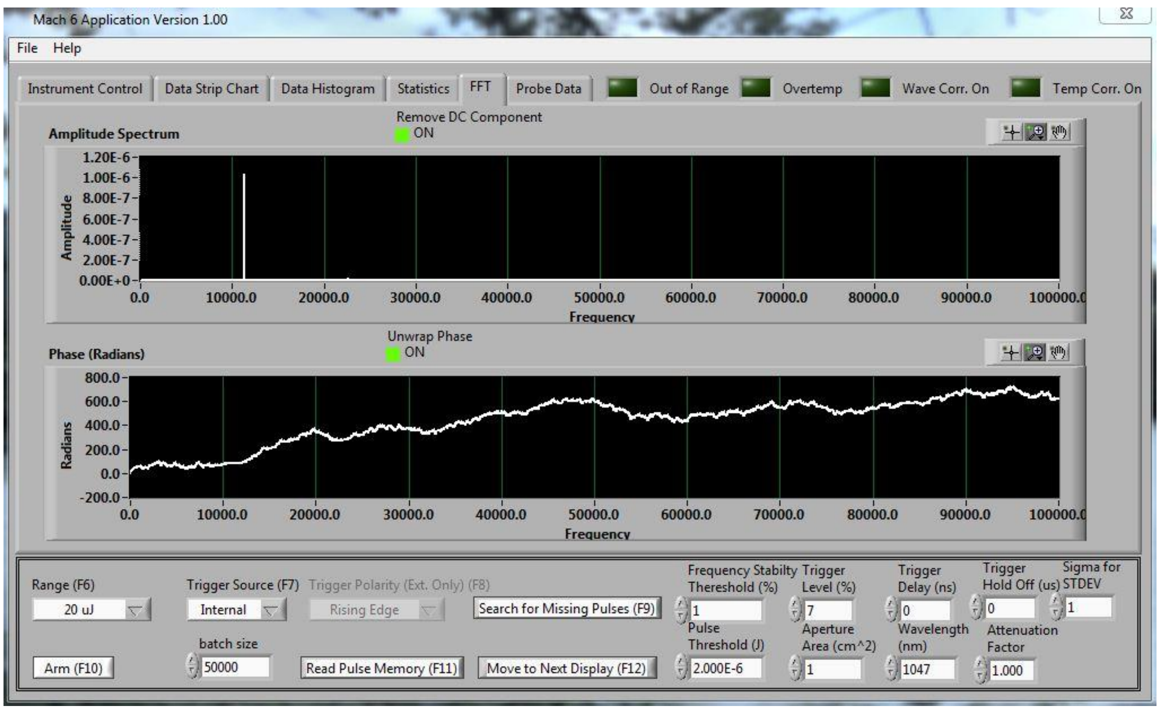


Figure 7, FFT Display

The function of the controls and indicators are:

Remove DC Component

Removes the DC component from the FFT. This control must be set before reading the data from the instrument or a saved data file.

Unwrap Phase

Unwrap Phase, when set to TRUE, enables phase unwrapping on the output phase Amplitude Spectrum Phase.

3.10. THE PROBE DATA DISPLAY

Figure 8 shows the Probe Data Display of the Applications Software.

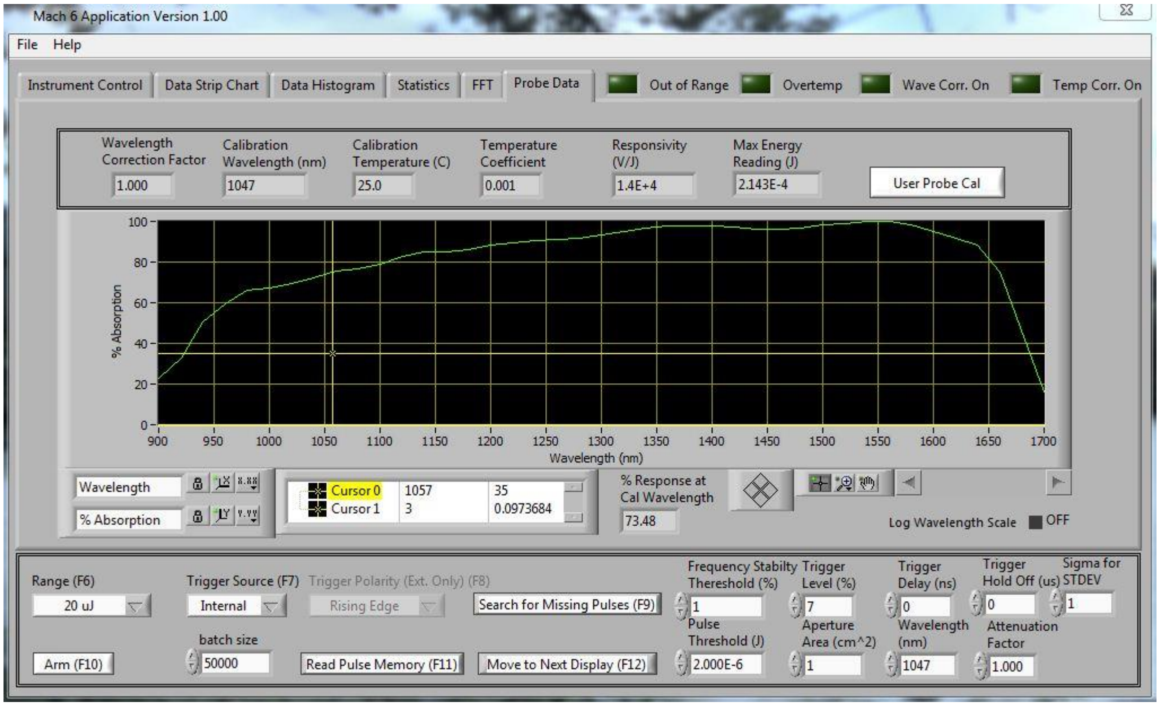


Figure 8, Probe Data Display

The functions of the controls or indicators are:

Wavelength Correction Factor

The responsivity correction factor that corresponds to the wavelength response of the sensor. Note that this is only active when wavelength is on and the set wavelength is different than the calibration wavelength.

Calibration Wavelength

The wavelength of the laser used to calibrate the sensor.

Calibration Temperature

The temperature of the sensor at calibration.

Temperature Coefficient

The temperature coefficient of the sensor. This is used in the temperature correction algorithm.

Responsivity

The responsivity of the sensor at the calibration wavelength and temperature.

Log Wavelength Scale

Toggles the wavelength axis of the absorption plot between log and linear scale.

% Absorption Plot

The absorption curve of the sensor versus wavelength. This data is used along with the calibration wavelength and the user's laser wavelength to calculate the wavelength correction factor.

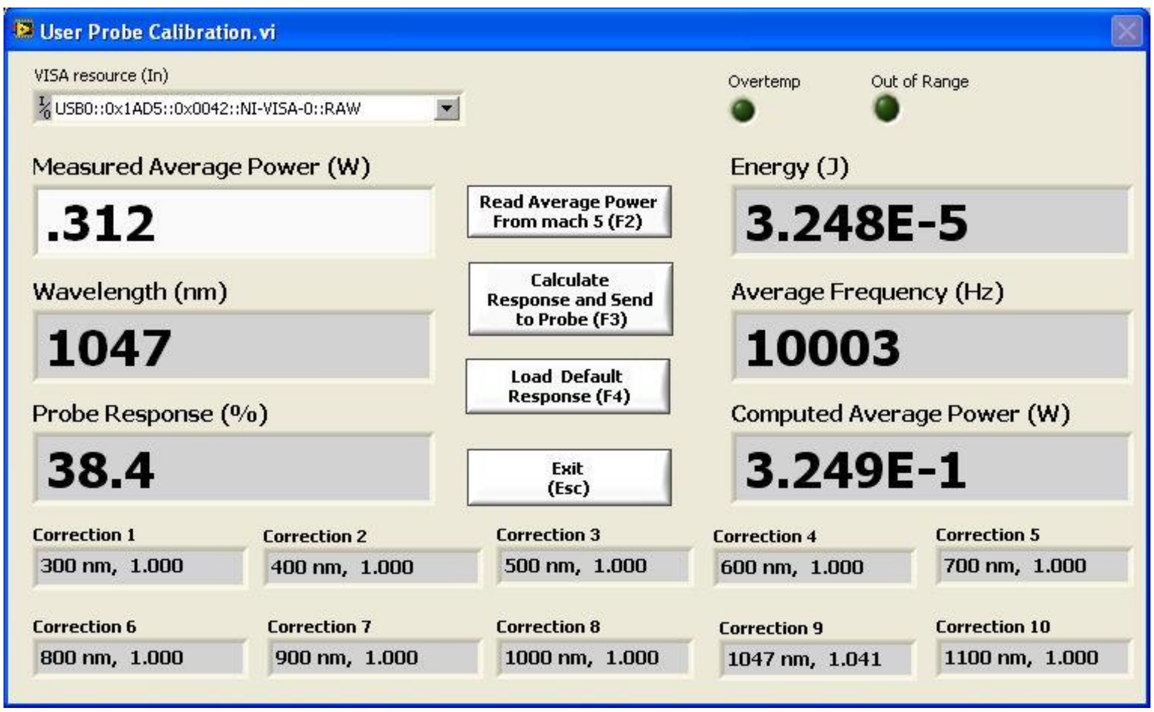
Max Energy Reading (J)

The maximum energy that the instrument can read before the internal circuitry is saturated. The instrument ranges are fixed in decade intervals, so if the maximum energy is 15mJ, the maximum available range will be 20mJ, but the instrument will only read up to 15mJ in that range.

Note that the maximum energy is dependent on the sensor responsivity. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges. If this occurs, the maximum energy will also change.

User Probe Cal

This control calls a VI that allows the user to set a specific wavelength response for the probe in use. The response will be stored in the probe memory. This allows for a user calibration of desired wavelengths. Wavelength Correction must be set to ON for this VI to work correctly. Make sure the instrument is correctly set up for measurements and is triggered before calling this VI. Use the Live Mode if necessary to ensure this.



The Controls are:

Measured Average Power

Enter the measured average power from your Power Meter Here. MACH 6 will use this to compute a new calibration factor for the wavelength in use and store it in the probe in use.

Read Average Power From MACH 6

Arms the instrument for a data gathering run, takes the measurement batch and then extracts the Energy and Frequency to use in calculating the average power.

Calculate Probe Response and Send to Probe

Reads the current probe wavelength response curve, calculates the new response point from the data, then writes the new calculated Probe Response to the Probe memory.

After the probe EPROM is written, MACH 6 will be reset to ensure the new data is correctly read from the probe.

Load a Default Probe Response

Write a selectable default Probe Response to the Probe memory.

After the probe EPROM is written, MACH 6 will be reset to ensure the new data is correctly read from the probe.

Exit

Exits the VI and returns to the main display. The new probe response table will be stored and used until a new one is written by the user. It is persistent over a power down.

The Indicators are:

Wavelength (nm)

Wavelength in nm. MACH 6 will use this to determine the probe wavelength response index for the new calibration factor for the wavelength in use.

Probe Response (%)

The calculated probe response at the wavelength in use. The VI uses the measured power from the user input and the measured power from MACH 6 to calculate the new response point. It then uses the new response and the selected wavelength to write the new point into the probe EPROM.

Energy (J)

The mean pulse energy in the data set.

Average Frequency (Hz)

The measured average frequency of the data set.

Computed Average Power (W)

Average Power = Frequency x Energy.

4. OPERATING MACH 6 WITH THE APPLICATIONS SOFTWARE

Plug the power supply and probe into the MACH 6 instrument. Start the application software. The software will set itself to the Instrument Control Tab and initialize contact with the instrument. It will then set itself to the Probe Data tab and read the required information from the probe. The software will then configure itself for the ranges appropriate to the probe and illuminate the Initialization Complete LED. The system is now ready for use.

4.1. GETTING READY TO MEASURE DATA

The MACH 6 instrument and applications software provide a versatile high speed measurement system. It must be properly set up to work well. The following sections discuss the controls that set up the instrument for measuring data.

4.2. RANGE SETTING

The available ranges are dictated by the probe in use. Use the range control to set the range to a value appropriate for the expected energy. Note that energy values above the range value can be measured, but accuracy may be reduced. In general, the smallest range that will contain the expected energy should be used, i.e., if the maximum energy to be measure is 189µJ, the use the 200µJ range. Note that this energy can be measured in the 2mJ range with a trigger level below 9%, or an external trigger, but more accurate results will be obtained in the 200µJ range.

4.3. TRIGGER LEVEL SETTING

If internal trigger is used, then the trigger level is set to a value that is less that the lowest expected energy. For example, energies from 1.8mJ to 15mJ are expected. Select the 20mJ range, and set the trigger level to less than 1.8 / 20 x 100 = 9 %. You may have to experiment with the trigger level until the trigger LED illuminates.

4.4. TRIGGER SOURCE SETTING

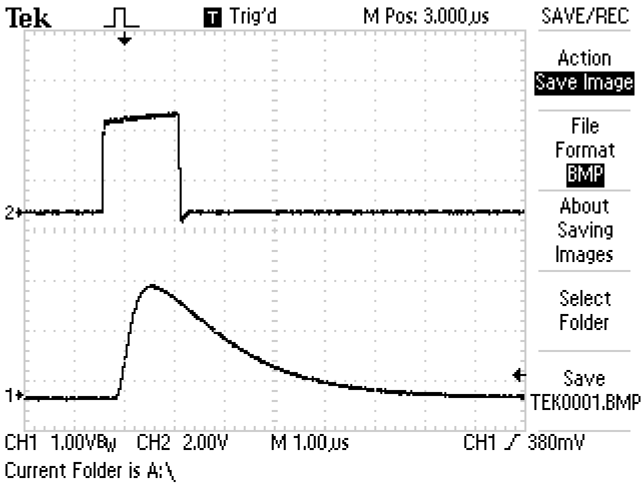
The trigger source can be set to internal or external. Internal trigger generates a trigger event whenever the pulse exceeds the trigger level. External triggering generates a trigger even whenever a TTL pulse is received on the External trigger input. A measurement is taken when a trigger even is generated, so with external triggering missing or runt pulses can be discovered.

4.5. TRIGGER POLARITY (SLOPE) SETTING

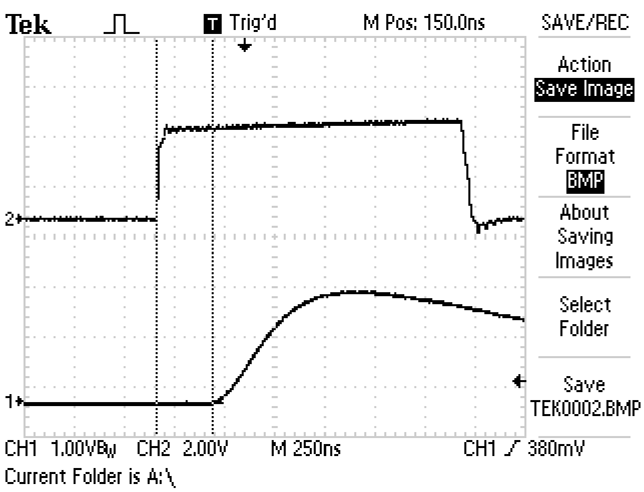
In external trigger mode, the rising or falling edge of the TTL pulse may be selected as the trigger event.

4.6. TRIGGER DELAY SETTING

The MACH 6 instrument samples the pulse being measured to determine the pulse energy. In order to accurately measure the energy, the trigger event must be temporally aligned with the pulse. This alignment is accomplished by setting the trigger delay. For internal triggering, the delay is set to the default value of 0ns and the user need not do anything. When set to internal triggering the instrument compares the amplitude of each pulse from the sensor to the set trigger level. If the pulse amplitude exceeds the set trigger level, then a trigger is generated by the instrument. For external triggers, if the TTL trigger occurs within less than 100ns of the emission of a laser pulse, then the default value will suffice. If used with external trigger, the timing relationship between the external TTL trigger and the laser firing event can be accounted for by setting the delay appropriately. The available range is -932ns to 2863ns. The figure below shows an external trigger pulse and the analog out from the MACH 6 measured on an oscilloscope.



If the trigger is set to external, with a rising edge polarity, then the temporal relationship between the rising edge of the trigger trace and the rising edge of the pulse trace must be known. The figure below is the same as above with the time base expanded and a set of cursors turned on.



The delay is seen to be approximately 300ns. This will be the trigger delay setting. The delay to the falling edge of the trigger pulse is -1250ns. Since the range of delay is -932ns to 2863ns, setting the polarity to falling edge would result in inaccurate measurements.

Note that when the instrument is set back to internal trigger, the polarity is reset to rising edge, and the trigger delay is reset to 0ns.

4.7. TRIGGER LEVEL TRACKING SETTING

This applies to Internal Trigger Mode only. Since the MACH 6 uses a hardware trigger, with a Pyroelectric probe the pulse that creates the trigger exhibits a DC drift, the trigger level will appear to shift in relation to the pulse. At low duty cycle, the pulse baseline will be stable and triggers will occur as intended. With high duty cycles the pulse will drift negative. If this drift is greater than the set trigger level the instrument will stop triggering and miss pulses. To prevent this, the trigger level must be corrected as the pulse baseline drifts. Trigger Tracking monitors the DC level of the pulse and modifies the trigger level so it remains at the set level in relation to the pulse. When triggering stops or MACH 6 is disarmed, or trigger tracking is turned off, the trigger level returns to its unmodified state.

It is possible for the MACH 6 to lose track of the trigger under certain conditions. See figure 8.

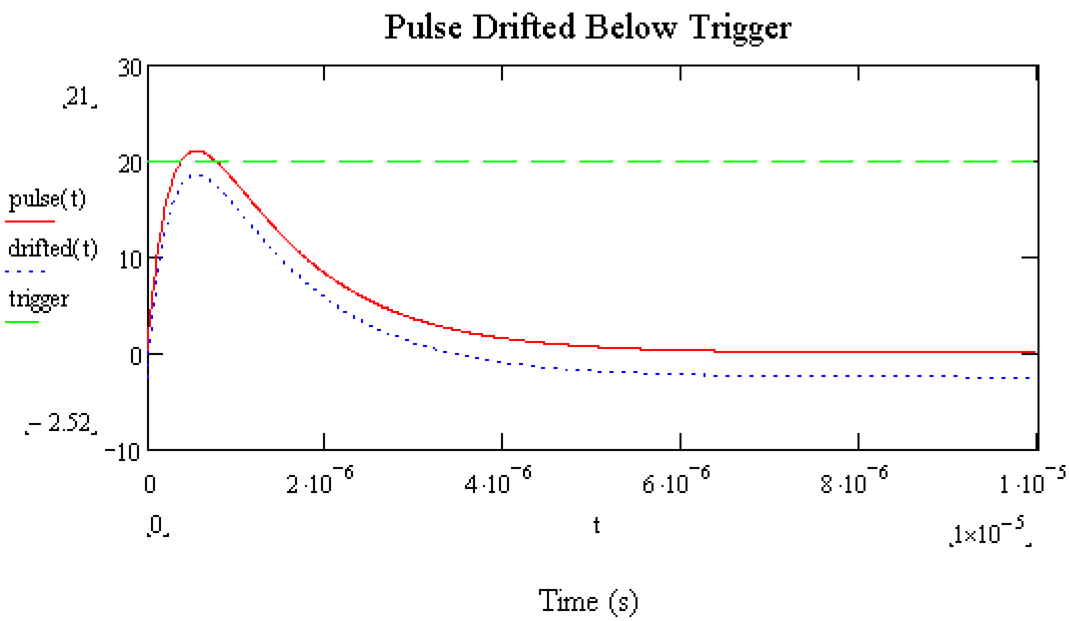


Figure 8, Pulse Drift

Suppose trigger level tracking is off and a pulse with energy of 21µJ is being measured at a very low repetition rate in the 200µJ range. The trigger level is set to 10%, or 20µJ, so data is being acquired. Now suppose the repetition rate is turned to 100,000pps and the signal drifts negative by 12%. The pulse energy is still 21µJ, but the "peak" of the pulse is now at 18.5µJ. This is below the trigger level and data is now being missed. If trigger tracking had been turned on, the trigger level would have followed the pulse as it drifted and no data would have been lost.

Now suppose in the previous example trigger tracking had been on. The trigger level would have followed the pulse down as it drifted 12%. If the MACH 6 is then disarmed, but the laser is left running at the same repletion rate, the pulse will stay at the same level, but the trigger will return to its non-corrected state. When MACH 6 is disarmed, no measurements are being taken and therefore no information about the pulse drift is available to use for trigger tracking. When MACH 6 is rearmed, no triggers will occur as the trigger level is still too high relative to the drifted pulse.

The solution to this is to readjust the trigger until the trigger LED illuminates, to use the Zero Baseline button, or to press the Autoset button.

4.8. ZERO BASELINE

The DC level of a pulse for a Pyro Electric sensor is dependant on the average energy. If the DC level drifts out of the ADC range and the Out of Range LED illuminates, pressing this button will cause the instrument to readjust the DC level in the instrument to compensate for this drift.

4.9. AUTOSET

This button calls the Autoset VI. This VI attempts to find the best range and trigger level for the signal being measured. The flow is:

1. Set the trigger source to internal.
2. Set the trigger delay to 0ns.
3. Set trigger level to 7%
4. Set the Range to Top Range.

5. Test for triggering.

If no triggers are present, the VI reduces the range to the next lowest and tests for triggering. It repeats this process until the lowest range is reached. If no triggers are present, it then reduces the trigger level 1% at a time until either triggering occurs or the minimum trigger level is reached.

When a trigger is found, the VI returns the discovered setup to the Instrument Controls Display.

4.10. MEASURING DATA

Once range and trigger setting have been made, and the trigger LED is illuminated, then data can be acquired. Press the ARM button. The ARM LED will illuminate indicating that pulses are being measured. The MACH 6 can store 4,194,303 pulses in internal memory. At 100,000 PPS, this is over 40 seconds of data. At 1,000 PPS, this is almost 70 minutes of data. Pressing the ARM button again stops data acquisition and the pulses are now stored in the MACH 6 memory and are ready to be retrieved and analyzed. If an event occurs during pulse measurement that could potentially corrupt the measurement, then that pulse will be discarded. The significance of this is that the first pulse of a batch taken after an arm is always discarded. Since the arm command is sent asynchronous to the laser pulses, and then the first trigger event after the arm could occur on the tail of the pulse, resulting in a lower measurement than expected. To avoid this case, the MACH 6 will discard this first measurement. In most cases this is not an issue, but if a set number of pulses are being sent by the laser, as in a burst mode, then MACH 6 must be set to a batch size of one less pulse.

4.11. RETRIEVING DATA

Press the Read Pulse Memory Button. This control calls a user prompt that asks for the pulse offset and the number of pulses to retrieve from pulse storage memory. Once that information is acquired, the pulse memory is read. The destination of the pulse memory is dependant on the state of the Read to File and Read to Display the check boxes. Note that both boxes can be checked.

Alternatively, the Auto Read Batch box on the Instrument Controls Tab can be checked. This will cause the entire measured batch to be automatically read into the selected data target, files, displays, or both as soon as the batch is taken.

The pulse memory is capable of storing up to 4,194,303 pulses. This is a large volume of data and it can be time consuming to retrieve all of it at once. The pulse offset and number of pulses to retrieve controls make this manageable. As an example, suppose there are 2 million pulses in the memory. The user can ask for this data in batches of 500,000 pulses at a time in 4 batches:

Read 1, pulse offset = 1, number of pulses to retrieve = 500,000
Read 2, pulse offset = 500,001, number of pulses to retrieve = 500,000
Read 3, pulse offset = 1,000,001, number of pulses to retrieve = 500,000
Read 4, pulse offset = 1,500,001, number of pulses to retrieve = 500,000

The response of the application to large pulse batches will depend on the host PC. A test MACHine with a 2.66GHz dual core processor and 3GB of memory retrieved 500,000 pulses to a data file in 7.9 seconds. The retrieval to the display took 20.9 seconds. The extra time is due to the processing of the large data arrays in the application.

4.12. ANALYZING DATA

The MACH 6 Applications Software has 4 data analysis displays. There is a strip chart for a visual representation of laser stability. There is a Histogram for a visual representation of the pulse distribution. There is an FFT display that allows the use to look for interference signals in the data. Last, there is a statistics display that computes commonly used statistical measurements.

4.13. MISSING PULSES

The MACH 6 Applications software is capable of detecting missing pulses in two ways.

Missing pulses below a user set threshold.

When the Search Data for Missing Pulses button is pressed, the current data set is examined. Any pulses with energy less than the threshold are flagged as missing, and there time stamps are recorded and displayed. This can be used with internal and external triggering, but it is most effective when used with external triggering.

Missing pulses due to missing time stamps.

With internal triggering, if the pulse is below the trigger level, no trigger will occur, but the period timer will still be running. This means that the period will be longer by at least 2x ± the frequency stability of the laser between the pulses adjacent to the missing pulses. The applications software examines the pulse data for this condition and records the time stamps where the period is discontinuous. From the continuous period data, the true period can be found and used to count how many pulses were missing in the discontinuities.

The % Frequency Stability Threshold setting determines how much time stamp mismatch is allowed when measuring the true frequency.

Other data analysis may be performed by importing the saved data files into a software package such as MathCad.

4.14. DATA CORRECTION

The MACH 6 system is capable of correcting data for wavelength and temperature variation from the calibration values. Both of these corrections can be disabled if so desired.

4.15. WAVELENGTH CORRECTION

Wavelength correction is done in the MACH 6 instrument. When a wavelength different from the calibration value is selected, the internal gains of the instrument are changed to normalize the response of the probe to the calibration wavelength. Since the sensor responsivity can vary significantly with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges. If this occurs, the instrument will set itself to the currently set range if it is still available. If it is not, the instrument will set itself to the next available range.

The response of the probe is stored in the probe memory and is read when the MACH 6 is powered on. It is plotted on the Probe Data display

4.16. TEMPERATURE CORRECTION

Temperature correction is done in the MACH 6 Application Software. When a temperature different from the calibration value is selected, the software computes the correction factor based on the responsivity temperature coefficient and the variation form the calibration value. Since temperature induced variations are typically a few percent or less, no gain rescaling is needed to adequately compensate the measurements.

4.17. PULSE MEMORY

MACH 6 contains an internal memory for storing measured pulse data. Due to the high repetition rate that MACH 6 can measure, there is no real time display. Data is retrieved from pulse memory after it has been acquired and displayed using the Applications Software. The internal memory can be read to either the displays, to a file, or both. Reading the pulse memory does not remove the data from the memory. The same data can be read multiple times if desired. Data will be lost if:

1. The memory is tested. The memory test writes patterns to the pulse memory and then verifies those patterns. Any stored test data will be overwritten. Requesting a memory test will cause the software to prompt the user to ensure this is the intended action.

2. The memory is cleared. The memory clear writes zeros to the pulse memory. Any stored test data will be overwritten. Requesting a memory clear will cause the software to prompt the user to ensure this is the intended action.
3. The MACH 6 is powered down. The pulse memory is SDRAM and is a volatile memory.

4.18. FILE MANAGEMENT

After data has been acquired, it may be saved to an external file for later analysis, either by the Applications Software or some other software package of the users' choice. The Applications Software can open, close, and copy an open file to the Applications Software displays.

4.19. OBTAINING HELP

There is context sensitive help available by selecting the Show Context Help item in the help menu. A help window will appear when the mouse cursor is placed over a control or indicator.

There is a compiled help file that can be called by selecting the Help item in the help menu.

5. MACH 6 COMMAND SET

All commands and replies are followed by a carriage return (0x0D) and a line feed (0x0A). If a command is used with no arguments it will become a query. All commands are case insensitive. All commands reply with:

OK if the command executed correctly.
ERR if the command could not be executed.

All Queries reply with the item that was queried or Err if the query could not be executed.
The host software must wait for an instrument reply before executing a subsequent command or query. The instrument will reply to all commands. This is necessary to ensure robust USB operation.

The MACH 6 instrument reports to the host as a USB raw device. Communication with the instrument is done with LabVIEW Vis using a USB driver supplied by National Instruments. This allows the programmer to use standard LabVIEW VISA Vis to communicate with the MACH 6 instrument.

Gentec-EO provides a LabVIEW library of the following commands to facilitate building custom interfaces.

Command/Query	Usage
VER	Queries the Firmware Version. Argument used is which processor to query. A 0 queries the Blackfin processor, a 1 queries the MSP processor. Example. Send: ver0CRLF Reply: BF 1.01.00CRLF
IDN	Queries the Instrument Identification. No argument is used. Example. Send: idnCRLF Reply: MACH 6 InstrumentCRLF
TST	Tests the Instrument internal pulse memory. No argument is used. Note that testing the pulse storage memory is destructive of any pulse data currently stored. Example. Send: tstCRLF Reply: SDRAM PASSED ACCESS TESTSCRLF
DMP	Reads the internal pulse memory. Arguments used are the offset and number to retrieve. The pulse memory is capable of storing up to 4,194,303 pulses. This is a large volume of data and it can be time consuming to retrieve all of it at once. The pulse offset and number of pulses to retrieve controls make this manageable. As an example, suppose there are 2 million pulses in the memory. The user can ask for this data in batches of 500,000 pulses at a time in 4 batches: Read 1, pulse offset = 1, number of pulses to retrieve = 500,000 Read 2, pulse offset = 500,001, number of pulses to retrieve = 500,000 Read 3, pulse offset = 1,000,001, number of pulses to retrieve = 500,000 Read 4, pulse offset = 1,500,001, number of pulses to retrieve = 500,000 Example. Send: dmp1,250000CRLF Reply: Pulse data starting with memory location 1 up to memory location 250000. See the section on data format for information on decoding the pulse data.
CLR	Clears the pulse memory. No argument is used. Note that clearing the pulse storage memory is destructive of any pulse data currently stored.

	Example. Send: clrCRLF Reply: OkCRLF
ARM	Arms the Instrument for pulse capture. Argument used is the number to capture, or 0 to stop capture. Arming the instrument clears any existing data from the pulse memory, then enables trigger detection. As each pulse is measured, the result is stored in pulse memory, up to 4 million pulses. (4,194,304) When the pulse memory is full, measurement continues but the data is discarded. Note that after arming the instrument you should not send any commands or queries other than the abort command, arm0. This is done to prevent the instrument from losing pulse data while responding to commands or queries. While capturing the batch, the instrument will send "Working" to the host. This bus traffic will not interfere with the pulse capture. When the requested batch has been captured, the instrument will send DISARMED to the host to signal the batch is complete. If during the batch the arm0 command is sent, the instrument will return DISARMED and stop data capture, but any pulses measured prior to the abort will still be saved in memory for retrieval. Example. Send: arm200000CRLF (capture 200000 pulses) Reply: As outlined above
CNT	Returns the number of pulses currently stored in the pulse memory. No argument is used. Example. Send: cntCRLF Reply: 200000CRLF
TRG	Sets or Queries the instrument trigger level. Argument used is the trigger level in % of the set range. Example. Send trg15CRLF sets the trigger level to 15% of the set range. Reply OkCRLF trgCRLF queries the current trigger level. Example trgCRLF Reply 15.0CRLF
RNG	Sets or Queries the instrument range Argument used is the range index. See the table below for ranges and indices. Note that not all ranges will be available for a given sensor. Use the min and max queries to determine which ranges are in use. Example. Send rng27CRLF sets the range to index 27, the 30mW or 30mJ range. rngCRLF queries the current range. Example rngCRLF Reply 27CRLF
MAX	Returns the maximum range index for the head in use. No arguments are used. Example

	Send maxCRLF Reply 10CRLF
MIN	Returns the minimum range index for the head in use. No arguments are used. Example Send minCRLF Reply 4CRLF
MRD	Returns the maximum reading for the head in use. No arguments are used. This is the maximum energy that the instrument can read before the internal circuitry is saturated. The instrument ranges are fixed in decade intervals, so if the maximum energy is 15mJ, the maximum available range will be 20mJ, but the instrument will only read up to 15mJ in that range. Note that the maximum energy is dependent on the sensor responsivity. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges. If this occurs, the maximum energy will also change. Example Send mrdCRLF Reply 276.7E-6CRLF, The maximum reading is 276.7uJ. To
SRC	Sets the trigger source for energy measurement. Argument is the source index. If no argument is sent, the query returns the trigger source. Example Send src1CRLF Trigger source is external. Send src0CRLF Trigger source is internal. Reply OKCRLF Example Send srcCRLF Reply d,dCRL, where d is the external and internal trigger setting, so 1,0 is set to external, 0,1 is set to internal.
DLY	Sets the trigger delay. Argument is the delay in ns. If no argument is sent, the query returns the trigger delay. Example Send dly1500CRLF Trigger delay is 1500ns. Reply OKCRLF Send dlyCRLF Reply 1500CRLF
POL	Sets the trigger polarity for the external trigger pulse. Argument is the polarity index. If no argument is sent, the query returns the trigger source. Example Send pol1CRLF Trigger polarity is rising edge. Send pol0CRLF Trigger polarity is falling edge. . Reply OKCRLF Example Send polCRLF Reply dCRL, where d is the polarity index

WAV	Sets the wavelength. Argument is the wavelength in nm. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges. Example Send wav1064CRLF Reply with the following: min range, max range, current rangeCRLF Example Send wavCRLF Reply 1064CRLF
WCM	Enables the wavelength correction. Argument is 0 or 1. Since the sensor responsivity varies with wavelength, turning Wavelength Compensation on may cause a rescale of the available ranges.1 turns it on, 0 turns it off Example Send wcm1CRLF Reply with the following: min range, max range, current rangeCRLF Example Send wcmCRLF Reply 1CRLF
TRK	Enables the trigger DC correction. Argument is 0 or 1. 1 turns it on, 0 turns it off. This applies to Internal Trigger Mode only. Since the MACH 5 uses a hardware trigger, and the pulse that creates the trigger exhibits a DC drift, the trigger level will appear to shift in relation to the pulse. At low duty cycle, the pulse baseline will be stable and triggers will occur as intended. With high duty cycles the pulse will drift negative. If this drift is greater than the set trigger level the instrument will stop triggering and miss pulses. To prevent this, the trigger level must be corrected as the pulse baseline drifts. Trigger Tracking monitors the DC level of the pulse and modifies the trigger level so it remains at the set level in relation to the pulse. When triggering stops, or MACH 5 is disarmed, or trigger tracking is turned off, the trigger level returns to its unmodified state. In general, this feature is only needed for Pyroelectric sensors. Example Send trk1CRLF Reply OkCRLF Example Send trkCRLF Reply 1CRLF
TRQ	Returns the trigger state. No arguments are used. Sends 0 if the instrument is not triggered, 1if it is. Example Send trqCRLF Reply 0CRLF
FAC	Returns the current wavelength correction factor. No arguments are used. Sends 1.00 if wavelength correction is off. Example Send facCRLF Reply 1.00CRLF

LIV	Sets the live mode acquisition. Argument is 0 or 1. 1 turns it on, 0 turns it off. In Live mode the instrument functions as a monitor. It measured in real time, but does not save any pulse data and sends sampled data to the host at a 10Hz rate. Example Send liv0CRLF Reply OkCRLF
HLD	Sets the trigger holdoff. Argument is the hold off in µs. If no argument is sent, the query returns the trigger holdoff. After a trigger event the instrument will not trigger again until the hold off expires. This is useful for bursts of pulses at a given rep rate. Supposed there are bursts of 5 pulses occurring every 10us and the bursts themselves occur every 200us. Setting to hold off to 50us will cause only the first pulse in the 5 pulse burst to be measured. Setting the trigger hold off to zero disables trigger hold off. Example Send hld15RLF Trigger holdoff is 15 µs. Reply OKCRLF Send hldCRLF Reply 15CRLF
CLK	Returns the internal system clock speed in MHz No arguments are used. This value is used to compute the pulse frequency in Live mode. In live mode the pulse time stamps are not sent as the data is sampled at 10Hz. Instead, the period counts are sent. Dividing the clock rate by the period counts yields the pulse frequency. Example Send clkCRLF Reply 240000000CRLF
SMT	Smart Trigger Monitor command. Arguments are the low Level, the high level as a percentage of the set range, the pre and post trigger sizes. Sets trigger event parameters so you can capture anomalous events. For example, you suspect the laser energy is drooping from 15uJ to 3uJ randomly. With the range set to 20uJ and the trigger event set to lower than the anomalous pulse energy, or less than 3uJ / 20uJ x 100 = 15%, so choose 10%. Alternatively, you can ensure a trigger for an anomalous event by choosing external trigger, but make sure the trigger and range parameter are correctly set before using the command. Set the low level to 2uJ, and the high level to 4uJ for this example. You can also set the pre and post event buffers to see the pulses leading up to and after the event. Then arm the instrument. It will fill the pre event buffer to the value set, and then wait for a pulse that falls within the parameters to occur. Once the event occurs, the instrument will fill the post event buffer and send the captured data. You will see the pulses that occurred prior to and after the event, and the pulse(s) that caused the event. Use the dmp<offset, amount> command to retrieve the pulses with the arguments set to 1, (pre + post + 1), or query the instrument for the pulses captured (cnt) and use that for the amount if the smart trigger mode was exited early. Example Send smt2e-6,4e-6,1000,1000CRLF Reply OKCRLF

	Send smtCRLF to exit the smart trigger monitor mode.
TPL	Returns the trigger pulse index when the smart trigger monitor is in use and has triggered. No arguments are used. The pulses used in the smart trigger monitors prefill buffer are in a circular array. This is the index of the trigger event that caused the buffer to stop filling and the monitor to go to the post trigger event buffer. Use this index to unwrap the circular buffer. The oldest data is after the trigger index, the newest is before it. As an example, suppose you set the pre and post trigger buffers to 1000 pulses. After the trigger event, the instrument will return 2001 pulses, 1000 pre trigger, the trigger pulse, and 1000 post trigger. Now send the tpl command and the instrument sends 463. Pulse 464 to 1000 are first in time, pulses 0 to 463 are next, then pulse 463, the trigger event, and then the last 1000 pulses. Example Send tplCRLF Reply 463CRLF

Range and Index Table

Range	Index
2pJ	0
20pJ	1
200pJ	2
2nJ	3
20nJ	4
200nJ	5
2uJ	6
20uJ	7
200uJ	8
2mJ	9
20mJ	10
200mJ	11
2J	12
20J	13
200J	14
2kJ	15

MACH Series Data Format

The MACH series instruments send 20 hexadecimal characters per measured pulse, followed by a carriage return and line feed.
0xTTTFRDDDPPPPPPPPEECRLF
The data is decoded as follows.
TTT is the hexadecimal representation of the sensor temperature x 10, in degrees Celsius.
F is the error flag byte.
R is the range byte
DDD is the 12-bit pulse measurement
PPPPPPPPP is the 32-bit time stamp in seconds
EE is the period exponent.

Example
The pulse datum sent is 0x11107AC669F3D72072CRLF
0x111 is 273. Dividing by 10 is 27.3 degrees Celsius.
0x0 is 0, so no error flags are set.

Bit Set to 1	Error
0	Out of range. The energy exceeded the set range
1	Over temp. The sensor was to hot
2	Buffer full error. Memory is full

0x07 is 7, so the range is 20uJ.

0xAC6 is 2758 counts.

The full-scale counts are 3072, so the measured energy is 2758 / 3072 x 20uJ = 17.96uJ

0x69F3D720 is 1777588000.

0x72 is 114, so the exponent is 114-128 = -14.

177758800 x 10^{-14} = 17.7758us for the time stamp.

6. RECYCLING AND SEPARATION PROCEDURE

This section is used by the recycling center when the monitor is at the end of its life. Breaking the calibration seal or opening the monitor will void the Monitor warranty.

The complete Monitor contains:

1 Monitor
1 USB cable
1 Instruction manual
1 Calibration certificate

6.1. SEPARATION:

Paper: Manual and certificate
Aluminum: Monitor enclosure.
Printed circuit board: inside the monitor.

6.2. DISMANTLING PROCEDURE:

To open the monitor:

Remove all the screws on both sides of the monitor:

Remove the PCB by sliding it out of the enclosure.

7. DECLARATION OF CONFORMITY

Application of Council Directive(s): 2014/30/EU EMC Directive

Manufacturer's Name: Gentec Electro Optics, Inc.
Manufacturer's Address: 445 St-Jean Baptiste, suite 160
(Québec), Canada G2E 5N7

European Representative's Name: Laser Components S.A.S.
Representative's Address: 45 bis Route des Gardes
92190 Meudon (France)

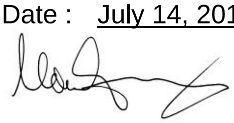
Type of Equipment: Laser Power/Energy Meter
Model No.: MACH 6
Year of test & manufacture: 2012

Standard(s) to which Conformity is declared:
EN 61326-1: 2006 Emission generic standard

Standard	Description	Performance Criteria
CISPR 11 :2009 +A1 2010	Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement	Class A
EN 61000-3-2:2006 +A2:2009	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)	Class A
EN 61000-3-3:2008	Electromagnetic compatibility (EMC) - Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems (for equipment with rated current ≤16 A per phase and not subject to conditional connection.)	Class A
EN 61000-4-2:2009	Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques- Electrostatic discharge.	Class B
EN 61000-4-3:2006 +A2:2010	Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques- Radiated, Radio Frequency, electromagnetic field immunity test.	Class A
EN 61000-4-4:2012	Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques- Electrical fast transient/burst immunity test.	Class B
EN 61000-4-5:2006	Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques- Surge immunity test.	Class B
EN 61000-4-6:2013	Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurements techniques- Immunity to conducted Radio Frequency.	Class A
EN 61000-4-11:2004	Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques- Voltage dips, short interruptions and voltage variations immunity tests	Class B Class B Class C Class C

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s) and Standard(s)

Place: Québec (Québec)
Date : July 14, 2016



(President)

8. UKCA DECLARATION OF CONFORMITY

UK CA

Application of Council Directive(s): 2014/30/EU EMC Directive

Manufacturer's Name: Gentec Electro Optics, Inc.
Manufacturer's Address: 445 St-Jean Baptiste, suite 160
(Québec), Canada G2E 5N7

European Representative's Name: Laser Components S.A.S.
Representative's Address: 45 bis Route des Gardes
92190 Meudon (France)

Type of Equipment: Laser Power/Energy Meter
Model No.: MACH 6
Year of test & manufacture: 2012

Standard(s) to which Conformity is declared:
EN 61326-1: 2006 Emission generic standard

Standard	Description	Performance Criteria
CISPR 11 :2009 +A1 2010	Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement	Class A
EN 61000-3-2:2006 +A2:2009	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)	Class A
EN 61000-3-3:2008	Electromagnetic compatibility (EMC) - Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems (for equipment with rated current ≤16 A per phase and not subject to conditional connection.)	Class A
EN 61000-4-2:2009	Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques- Electrostatic discharge.	Class B
EN 61000-4-3:2006 +A2:2010	Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques- Radiated, Radio Frequency, electromagnetic field immunity test.	Class A
EN 61000-4-4:2012	Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques- Electrical fast transient/burst immunity test.	Class B
EN 61000-4-5:2006	Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques- Surge immunity test.	Class B
EN 61000-4-6:2013	Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurements techniques- Immunity to conducted Radio Frequency.	Class A
EN 61000-4-11:2004	Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques- Voltage dips, short interruptions and voltage variations immunity tests	Class B Class B Class C Class C

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s) and Standard(s)

Place: Québec (Québec)
Date : November 29, 2021

(President)

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POWER & ENERGY METERS

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