

Daysimeter™ User's Guide

March 28, 2008

About the Daysimeter



The Lighting Research Center's (LRC) Daysimeter is a lightweight, head-mounted field research tool designed to measure a person's light exposure and activity while going about a normal routine. Self-contained and battery-operated, the Daysimeter records data for later retrieval.

Light reaching the eye has two effects on human behavior: 1) it enables us to see and 2) it affects a range of neuroendocrine and neurobehavioral responses, including the synchronization of our circadian rhythms to the 24-hour solar day. The Daysimeter is the first device to measure accurately the light (intensity, spectrum, timing, and duration) that reaches the cornea for visual and non-visual systems. The device has two internal optical sensors: one detects optical radiation corrected to the photopic response; the other has a filter that detects short wavelength light.

The Daysimeter also records head movements to differentiate between rest and active periods. A two-axis, on-board accelerometer measures the subject's activity.

Prior to the Daysimeter, light measurement devices have been calibrated to represent the spectral sensitivity of the daytime human visual system only. However, the lighting characteristics affecting many other biological systems, such as the circadian system, differ dramatically from those of the daytime human visual system.

Evidence is building that light can affect the rest/activity patterns of premature infants, can improve sleep quality in people with Alzheimer's disease, and may even be associated with increased risk of breast cancer in nightshift workers. Use of the Daysimeter will enable better characterization of our lighted environment, which will lead to better design of light sources, luminaires, lighting techniques, and lighting applications that will help maintain regular circadian and other biological functions.

The Daysimeter provides a means to move from a general, qualitative discussion of light to a quantitative characterization of light as a stimulus for a variety of biological responses affecting health and well-being.

How it works

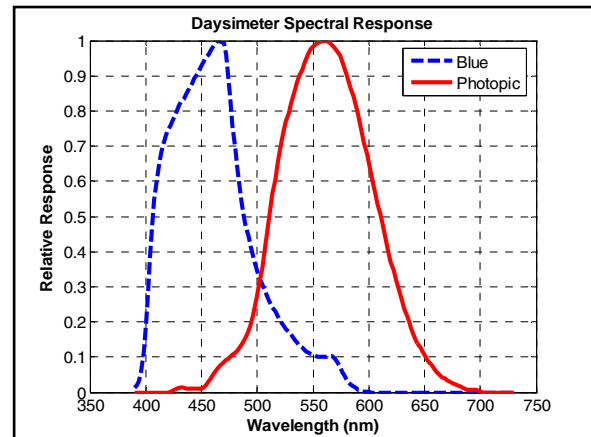
The Daysimeter is a carefully calibrated light and activity measurement device. Given the large dynamic range of light intensities people experience daily, the Daysimeter stores voltage data proportional to the logarithm of the photocurrents generated by each of the two photocells. A matched transistor array performs the linear-to-logarithmic conversion. Every Daysimeter has its own array of calibration constants determined by the LRC during calibration. These constants are used by the associated software to generate accurate light level measurements.

While acquiring data, the Daysimeter rapidly samples light readings from both photocells and from the accelerometers. Within a given second (s), 10 samples spaced every 0.01667 s are averaged and stored in volatile memory. Thirty of these once-per-second readings are again averaged and the average value is stored in nonvolatile memory. The accelerometers also generate voltage data, which is sampled once per s, and every 30 s the root-mean-square (RMS) value is stored in nonvolatile memory. Thus, the Daysimeter provides light and activity samples for subsequent data analysis with a 30 s resolution.

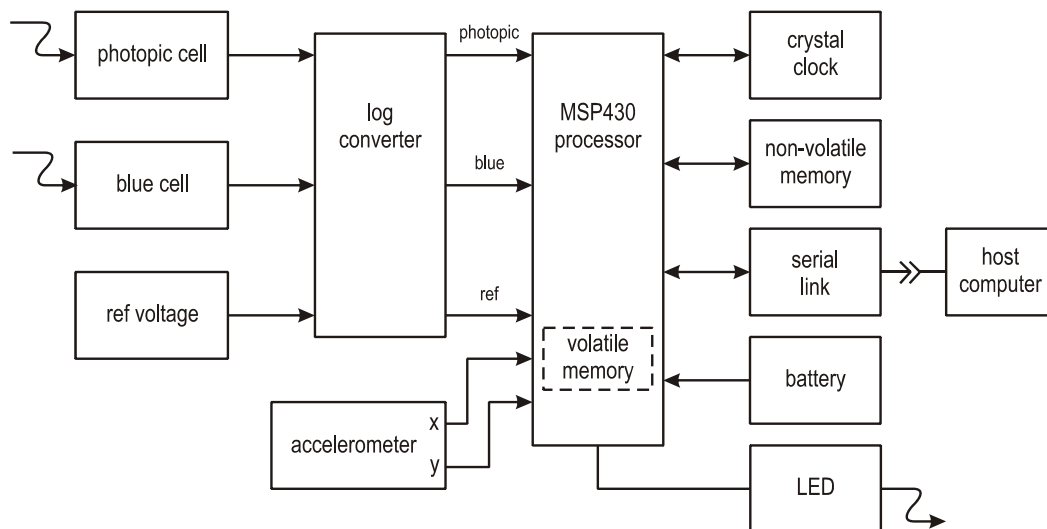


Measured values that are stored include:

1. Voltage associated with the logarithm of the photopic cell's current.
2. Voltage associated with the logarithm of the short-wavelength (blue) light cell's current.
3. Voltage associated with the logarithm of a reference current associated with the matched transistor array (an internal voltage needed for the logarithm conversion). This value is also used to provide an indication of ambient temperature.
4. RMS values of the x- and y-directions of the accelerometer's output. x- and y-directions are in the plane of the printed circuit board.



The Daysimeter has 51 x 4092 memory locations, yielding a maximum run time of 6,260,760 seconds (72 days). In practice, run time is limited by battery life (approximately 30 days of active logging).



Daysimeter block diagram

The Daysimeter software is designed to:

1. Control the Daysimeter and download data.
2. Convert the voltage data from the Daysimeter to photopic and circadian stimulus (CS) data.¹ It displays the data graphically along with the accelerometer and temperature data. The software can be used to extract data ranges from the complete data set.
3. Analyze the activity and light data which show entrainment-correlation functions. Aspects of these functions are depicted graphically using phasor diagrams.
4. Graphically display data from the Daysimeter as it acquires samples (live readings). This mode is typically used to demonstrate the function of the Daysimeter, as opposed to logging data.

¹ Rea, M. S., Figueiro, M. G., Bullough, J. D., Bierman, A. 2005. A model of phototransduction by the human circadian system. *Brain Res. Rev.* **50**, 213-228.

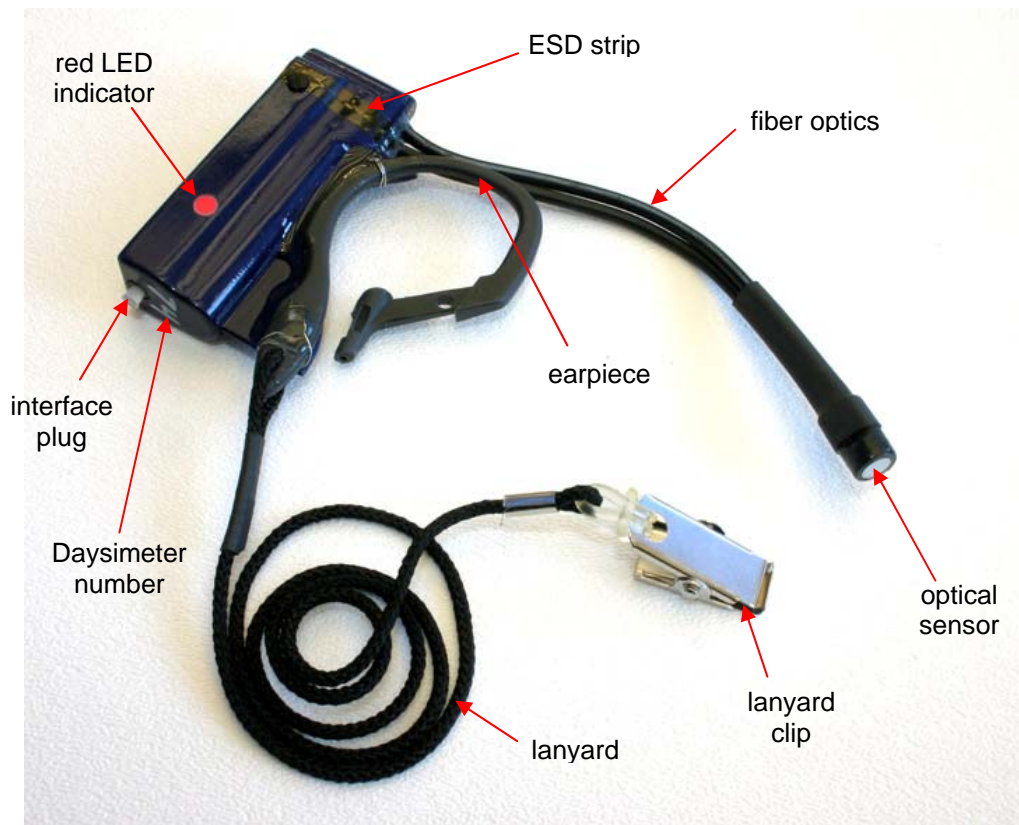


In addition to operation using the software discussed above, the Daysimeter can be controlled by sending ASCII character commands over the serial link using a terminal program such as **HyperTerminal**[®] (supplied with Microsoft[®] Windows[®]). Data can be downloaded from the Daysimeter and saved to a text file by using the "text capture" feature of HyperTerminal. See Appendix 1 for details on operating the Daysimeter in this manner.

Daysimeter components

The following components are involved in setting up and running the Daysimeter:

1. **Daysimeter** – light-exposure recording device that is worn behind the ear of the subject.
2. **Interface cable** – attaches the Daysimeter to a computer for setup and data retrieval.
3. **Windows[®]-based computer with USB port**
4. **Software** – Controls the Daysimeter, downloads data, and converts the raw downloaded data to time-stamped circadian stimulus data.



The Daysimeter and its components

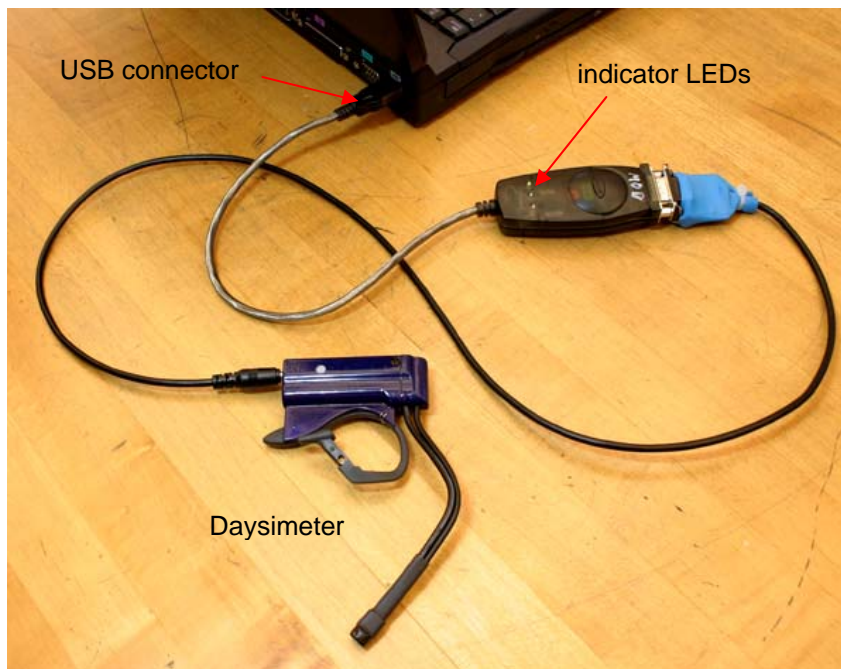


Daysimeter precautions

The Daysimeter is a precision electronic measurement device and should be handled as such. Please be aware of the following precautions when handling, using, or storing the Daysimeter.

- **Handling** – Please handle the Daysimeter carefully; dropping the instrument may cause damage. **Do not bend the fiber optics**—calibration of the instrument may be affected.
- **Temperature** – Do not subject the Daysimeter to extreme temperatures. The designed operating range of the Daysimeter is 0° to 45°C (32° to 113°F)
- **Water resistance** – The Daysimeter has some water resistance but is not waterproof. Exposure to extreme weather elements such as driving rain or heavy snow should be avoided. The Daysimeter should be removed and placed in a dry environment while showering or bathing. The interface plug should remain in place when the Daysimeter is not connected to the interface cable.
- **ESD caution** – The Daysimeter is a sensitive electronic device and has been designed to resist most static discharges. However, avoid using it in or near strong electrostatic, electromagnetic, magnetic, or radioactive fields. An inadvertent electrostatic discharge (shock) may cause the Daysimeter to reset, resulting in some data loss.
- **Storage** – The safest place to store the Daysimeter is the black container in which it was shipped. The foam lining of the box should protect it from most accidental mishandling and ESD.

Interface cable



The Daysimeter interface cable (attached to computer and Daysimeter)

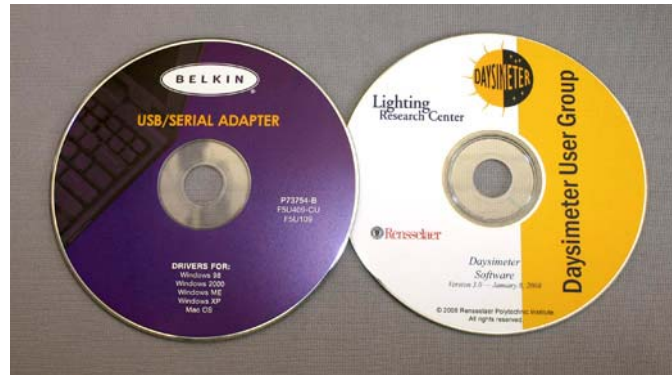
An interface cable is used to connect the Daysimeter to a host computer containing the appropriate software for control, data download, and storage. The cable is equipped with a USB/serial port adapter. The adapter has three indicator LEDs which show operation (green) and data transmittal (red) status.

The Daysimeter's internal battery charges when plugged into the computer via the interface cable (the computer must be on). Approximately 24 hours of charging will enable the Daysimeter to log data for up to 30 days.



Software

Operating software for the Daysimeter is provided on two CDs, a Belkin CD containing the USB/serial adapter driver; and a Daysimeter User Group CD which contains the National Instruments' Visa driver and the Daysimeter operating software. Installation and operation of the software is described later in this document.



Battery chargers

A multiple charger has been designed to charge up to 10 Daysimeter batteries at a time. The Daysimeters should not be left charging for longer than 48 hours when charging on the multiple charger or from a computer.

In addition, a 'trickle' or maintaining charger (not shown) may be used to maintain the Daysimeter's charge when it will be stored for periods longer than 1 month.



Multiple charger



How to wear the Daysimeter

The Daysimeter is worn over the left or right ear with the optical sensor facing forward, as shown in the photo below.



Daysimeter positioned properly (lanyard not shown)

Long hair or headwear (hats with brims) may impede the light entering the optics; it is best to avoid letting hair or hats cover or shade the optical sensor. Also, the Daysimeter should always point in a forward direction, i.e., not up or down. A piece of adhesive tape may be used to stabilize the Daysimeter on the ear so it does not move excessively (e.g., 3M Durapore™ tape works well).

As an added precaution, a lanyard is provided to protect the Daysimeter from falling to the ground while being worn. The lanyard should be clipped to the user's shirt collar or equivalent when in use.



Do not let hair interfere with the optics.



Do not let the Daysimeter point up (as shown) or down.



Adhesive tape may be used to hold the Daysimeter in place.

The Daysimeter should be worn throughout the day or night, whenever the subject is awake and performing normal tasks or duties. The Daysimeter should be removed, however, when bathing or showering. It should also be removed when sleeping; but if not worn, the Daysimeter should be placed near the user to continue monitoring light levels.



Daysimeter Operation

DO NOT ATTACH THE DAYSIMETER CABLE TO EITHER THE COMPUTER OR THE DAYSIMETER UNTIL ALL SOFTWARE AND DEVICE DRIVERS HAVE BEEN INSTALLED.

Software Installation

There are three pieces of software to be installed for effective operation of the Daysimeter.

First, install the driver software for the interface cable. Insert the Belkin USB/Serial Adapter CD and follow the manufacturer's instructions for installation. When prompted to reboot the computer, choose the option to **reboot later**, since subsequent parts of the installation process will require rebooting as well.

The Daysimeter software should be installed next. The software will require approximately 210 Mb of hard drive space. Open the CD in Windows Explorer. Inside the subdirectory, DaysimeterV4, is a file named setup.exe. Double-click to start and install per the on-screen instructions. This may take a few minutes.

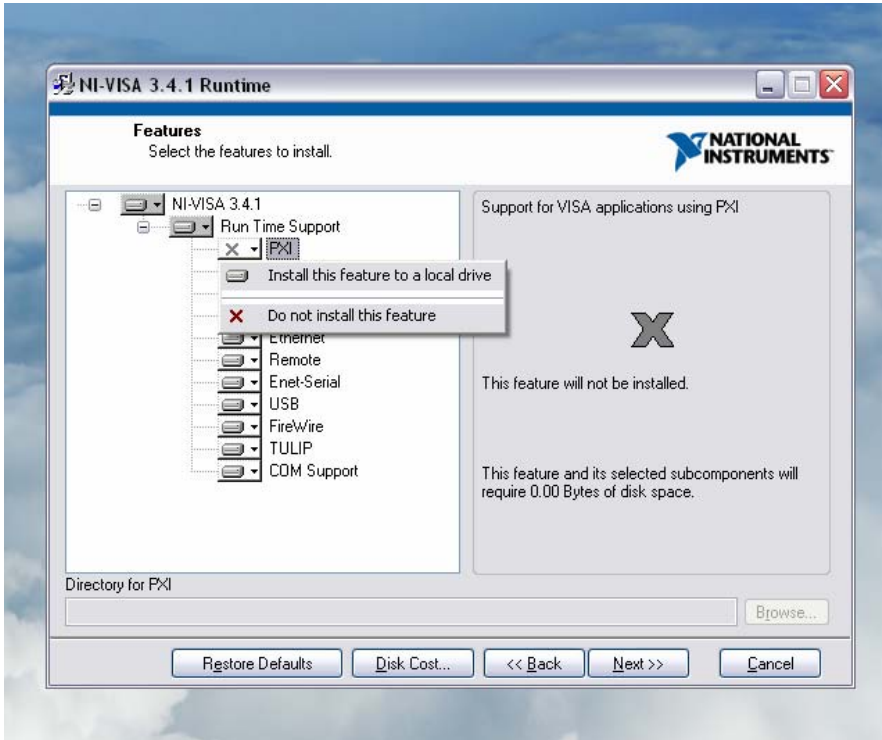


Accept the license agreement to allow the installation to proceed.



At the end of the installation sequence, the user will be prompted to reboot. Choose the option to **reboot later**, since the next part of the installation sequence will require a reboot as well.

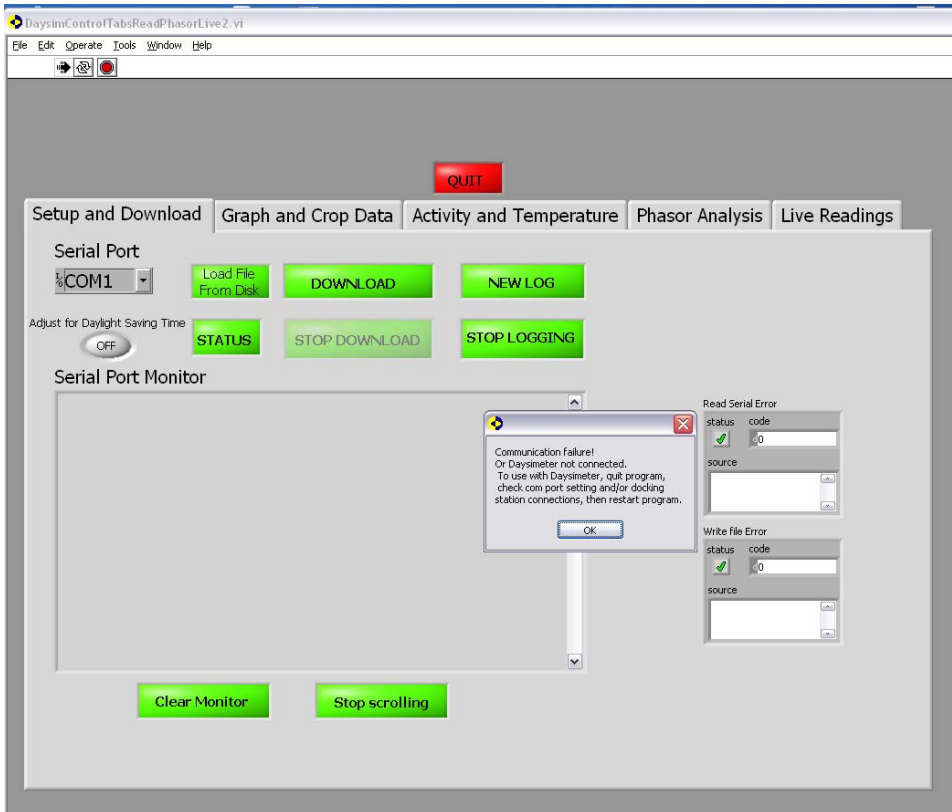
Install the Visa driver. Go back to the CD and double-click the file `visa341runtime.exe`. Use the unzip procedure to start installation. When installing Features, choose the Serial option by unselecting all the other Run Time Support devices (except Serial). For example, click the drive icon to the left of PXI and choose “Do not install this feature” from the pop-up menu. See figure below.



When the installation sequence is complete, the user will be prompted to reboot the computer. Select “reboot” at this time.

Once the software is successfully installed and the computer has rebooted, remove the Daysimeter’s interface plug and connect the interface cable between the Daysimeter and the computer’s USB port. Keep the plug in a convenient location—it will be replaced when the Daysimeter is ready to be worn.

Start the Daysimeter software by selecting DaysimeterV4 from the Start/Programs menu. Some computers may have firewall protection that will block program execution. Choose “Unblock” from the security alert screen if this occurs.

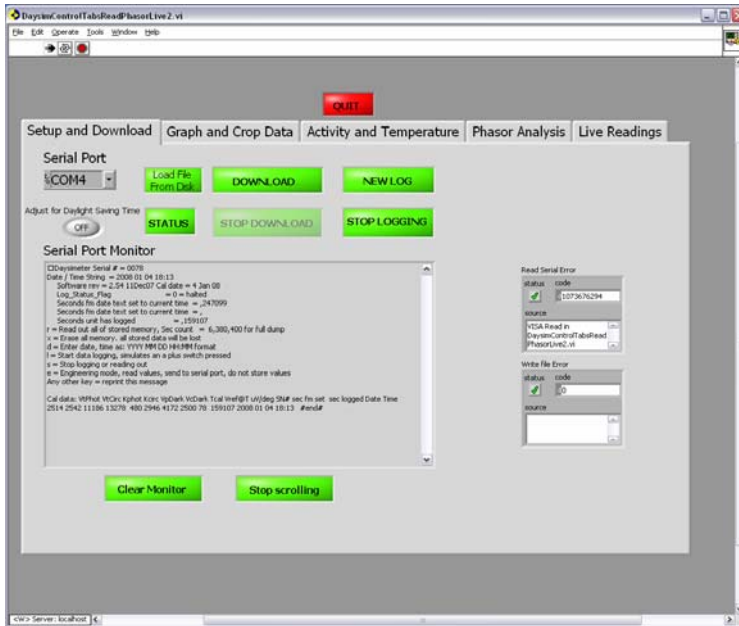


When first initializing the software, a Communication Failure alert will be displayed (shown in the screen capture above). Click OK to proceed.

Configure the serial port by choosing the COM port connected to the Daysimeter (usually the highest number in the drop-down serial port menu). Press the red QUIT button and restart the program by pressing the 'run' (arrow) icon in the upper left of the screen. The Serial Port Monitor display will become active after a few seconds, showing the Daysimeter serial number, date string, etc.



Setup and Download Tab



The Setup and Download screen initiates communication with the Daysimeter. Create a new log file by pressing “New Log.” Answer “Yes” to erase all previous data. After a few moments, the user will be prompted to reset the date and time. Click “Done” to proceed. In a few seconds, the Daysimeter will begin collecting data, displaying raw data values in the serial port monitor. The user can view the data graphically by choosing the Live Readings tab at the top of the screen.

The Daysimeter is now ready to be worn. Click “Quit” and detach the interface cable. A red LED on the side of the Daysimeter will now begin to flash once every 30 seconds to show that the instrument is logging. Replace the interface plug.

Other buttons on the Setup and Download screen:

- **Clear Monitor:** Clears the serial port monitor window.
- **Disable (Enable) Scrolling:** Stops or starts the scrolling of data on the screen.
- **Status:** Shows the Daysimeter serial number, date string, software version, and logging status of the connected Daysimeter. This button is helpful to verify the Daysimeter log status during setup and/or retrieval of data. If necessary, use the Disable Scrolling button to freeze the information in the window.
- **Stop Logging:** Stops the Daysimeter data logging process and any measurement processes. If pressed, no more data will be added and a new log must be initiated. This also places the Daysimeter in a low power mode to conserve battery life.
- **Download:** Launches a sequence of operations to capture and calibrate the information stored in the Daysimeter. Logging must first be stopped before downloading is attempted. Once the Download button is pressed, the data will begin to be transferred to the computer (this process may take a considerable amount of time, depending on the length of data collection. When complete, the user will be prompted to enter a filename to store the raw, uncalibrated log data. The download may be stopped at any time by pressing the **Stop Download** button. Only data transferred up to that point will be saved. Once the file is saved, the tab “Graph and Crop Data” is displayed, showing the calibrated light data retrieved from the Daysimeter.
- **Load File from Disk:** Loads a previously downloaded, raw, uncalibrated Daysimeter log file.



Graph and Crop Data tab

This part of the program enables the user to select a subset of the logged data for a given period of time for further analysis or saving in a spreadsheet format (tab-delimited file). Typically, the user would be brought to this tab following a data download. The user may also load a previously saved raw data file for manipulation.

Set the vertical cursors (yellow bars) to indicate the beginning and end of the data interval of interest. The vertical cursors may also be set by typing the time and date manually in the X column. Cursor 0 is, by default, on the left, and Cursor 1 is on the right.

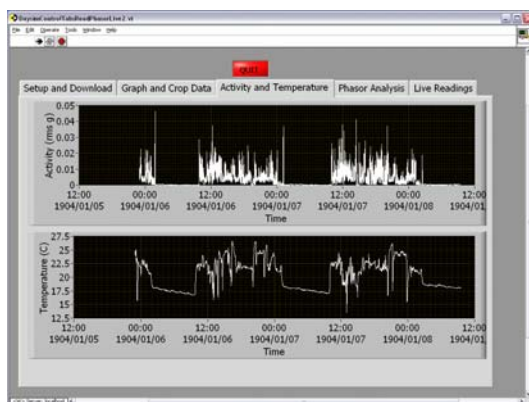


When the desired range is selected, press the flashing yellow button to crop the data. The user may save the cropped data as a spreadsheet (e.g., .xls extension for Excel), if desired.

By clicking on the Illuminance (lux)/Circadian Stimulus legend box, several graphic variables may be changed, i.e., color, graph type, line style, etc. Zoom and pan buttons are also available under the green Redo Crop and Save button.

Activity and Temperature tab

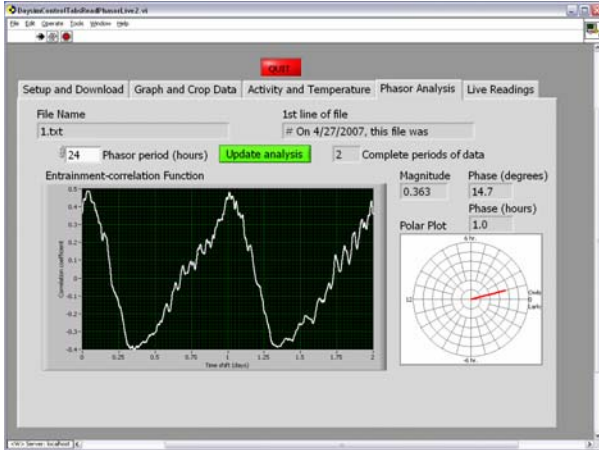
This tab shows the activity and temperature data corresponding to the selected interval shown on the Graph and Crop Data tab.





Phasor Analysis tab

This tab graphically displays the entrainment/correlation function and phasor information. The user may enter the phasor period desired, followed by pressing the Update analysis button, to display the entrainment-correlation graph and phasor polar plot.



Live Readings tab

This tab graphically displays data from the Daysimeter as it acquires samples (live readings). This mode is typically used to demonstrate the function of the Daysimeter, as opposed to logging data. If the Daysimeter is stopped, press the Run without Logging button to display live data as it is received.





Appendix 1

HyperTerminal Operation

HyperTerminal can be used to send and receive data from the Daysimeter. The commands consist of lower case ASCII characters as follows:

1. **r = read out all of the stored memory.** The device sends the contents of its nonvolatile memory to the host PC starting at the beginning of the log up to the last written memory location. After finishing the 51 line page of volatile memory that it is accumulating (filling empty memory locations with zeros), the device sends this data to the host PC, and then stops. Data at the end of the readout (consisting of zero values) can be ignored.

To dump the Daysimeter's stored data to a file:

- Go to the "Transfer" button on HyperTerminal's button bar and select "capture text."
- Enter file name and select "start."
- Type "r" to get the Daysimeter to dump all data.
- When the data have been downloaded, go to "capture text," and select "stop" to save the file.

Note: HyperTerminal WILL overwrite existing files without warning.

2. **d = enter the date-time text.** This is a text string of up to 40 characters, terminated by an "enter" ASCII character. This is typically used to establish an absolute time reference for the logged data. The software associated with the Daysimeter expects the string to be in the form of "YYYY MM DD HH:MM" (Year, Month, Date, Hour, Minute).

When the Daysimeter begins logging, the unit will record the seconds that have elapsed since the date string was set and when it started logging. This method enables a time stamps to be associated with the logged data.

It is possible to begin data logging without resetting the date time string. However, this can result in confusing indications of when the unit began logging and how long it actually logged. When erasing the data memory via the "x" command, the date time string is reset to "date string not set."

Note: There is no editor on the text string capture. If you make a mistake hit enter and start over.

3. **l (lower case "L") = start logging.** The Daysimeter LED will flash every 30 s while the unit is logging.
4. **s = stop logging or reading out data.** This takes the unit out of logging mode, reading out mode, or engineering mode, and puts it in a low-power, stopped mode.
5. **e = engineering mode:** This mode allows the user to take readings and send them to the serial port. However, it does not store the data. The accelerometer data displayed in this mode are proportional to g-force (not RMS values).
6. **x = erase all data memory. WARNING: This will permanently erase all stored data.** The software will ask, "Do you want to do this?" before the unit erases all data.

If you start logging without erasing the memory, the Daysimeter will overwrite the existing data. This can result in a confusing state where old data appears to be appended to the end of current data. **Note:** It is best to always erase old data before logging new data.

When the Daysimeter erases the data, the date time text is reset to "date string not set."



Any other ASCII character (i.e., keyboard key press) will display Daysimeter status information and a list of the commands given above.

Setting up HyperTerminal

1. Under "file" button, select "new connection."
2. On the "connect to" page, select "connect using" as com1 or com2, according to how the docking station is connected to the computer.
3. On the port properties page, select:
 - a. Bits per second = "9600"
 - b. Data bits = "8"
 - c. Parity = "none"
 - d. Stop bits = "1"
 - e. Flow control = "none"

Appendix 2

(This page should be photocopied, filled out, and retained as a record of each Daysimeter use.)

Deployment Checklist

Date started _____

User _____

Daysimeter number _____

Have previous data been downloaded from unit and saved? _____

Has the battery been charged? _____

Has the date-time string been set? _____

Has the unit been commanded to start logging? _____

Is the red LED flashing once every 30 seconds? _____

Has the interface plug been replaced in the Daysimeter base? _____

Post-logging Checklist

Date completed _____

Has the data been downloaded and saved? _____

Has the Daysimeter been stopped logging (low-power mode)? _____

Is the Daysimeter disconnected from the PC and the interface plug reattached? _____

If the Daysimeter will not be immediately reused, has the Daysimeter been connected to a battery charger (multiple charger or 'trickle' charger)? _____