SIGNALSOLUTIONS

Sensor Systems, Software, Sleep

PiezoSleep 4.0 **USER MANUAL**

May 2025

PiezoSleep 4.0

Version 4.0.9 – May 2025

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Contents

Introduction

The *PiezoSleep* 4.0 data collection software, written and compiled in LabVIEW, monitors and records high-throughput animal behavior-tracking experiments, which output several files for classifying behavioral states.

The user creates the base name for the files when the experiment starts, and extensions and suffixes are added to distinguish them. The basic pressure signal from the piezoelectric sensors is sampled at 120 Hz and saved with either a ***.bin*** or ***.binfb*** extension (*.bin* for rats, *.binfb* for mice). Features associated with sleep and wake behaviors are extracted from the pressure signal and saved every 2 seconds in a file with the ***.FeatVec***/***.FeatVecfb*** extension. The ***FeatVec*** file is read using *SleepStats*, our data analysis program, to characterize the sleep and wake behaviors over the duration of the experimental recording. The breath rate is estimated during sleep states every 2 seconds and stored in a file with a suffix and extension ***_br.Feat***/***_br.Featfb***. A measure of general activity is also computed in 2-second windows and stored in the file with the ***_at suffix.Feat***/***_at.Featfb*** extension.

During the recording process, the graphical user interface of *PiezoSleep* provides a variety of graphs, statistical summaries, and current sleep-wake states to monitor the data collection for real-time monitoring. This software supports the use of our data acquisition boxes (the Calimari, Squid, and Giant Squid boxes), accommodating up to 64 cage recordings simultaneously. These boxes contain data acquisition (DAQ) modules as well as power distribution circuits for the sensor amplifiers. The software described in this document automatically detects all devices configured on your computer. It will run on a PC with a minimum of Windows 7 operating system (32 or 64-bit) and a USB port. The installation of this software automatically installs drivers from National Instruments to configure the computer to stream data through the USB port if they are not already installed.

System Requirements

Windows 7 or later with 2GB or higher RAM.

Installation

1. To install the real-time sleep-wake monitoring software and support the National Instruments (NI) software, download and unzip the installation package via the instructions given with your purchase.

2. Transfer the file to the computer's hard drive, where data will be collected, and unzip the file. Once unzipped, the directory '*PiezoSleep*...' should have been created. Inside this directory is one labeled volume with an application file named ***setup***. Double-click this file to start the installation process. Follow the instructions in the prompts to complete the installation.

3. Once the installation process is complete, a shortcut named *PiezoSleep* will be created on the desktop. Double-clicking on the shortcut will launch the software program. This program can also be accessed from the start menu, under the *PiezoSleep* folder, or from the hard drive location it was saved to during the installation. When removing this software, this program can be identified in the ***Programs*** option under the ***Control Panel*** from the PC menus and removed.

4. After the software installation is complete, plug the data acquisition box into the PC USB port (and power it up if it requires external power). If this is the first time, the computer will start installing the driver and configuring the power, which may take a few minutes.

Computer settings to change before running PiezoSleep

During a recording, it is important to ensure your computer does not power down the USB ports or reboot after an operating system update. Otherwise, the program will stop, and no future data collection will occur. Computer power-saving features for a PC are often turned on in the default system setup. These can cause longer recordings (greater than a few hours) to halt. Check the following settings to ensure the computer will not power down the USB ports, go into sleep mode, or reboot for an update during an experiment recording.

1. Go to the ***Start*** menu and type *Device Manager* in the search bar (you may have to click the gear icon to get to the settings menu first to get the search panel). If you have an older operating system, you will see it listed under the ***Control Panel***. If you still don't see the option to open the *Device Manager*, you can try the keyboard shortcut ***Windows Key + R*** for the *Run Command* and type in the textbox ***devmgmt.msc***. Then press *OK* or *Enter*. This will instantly open the *Device Manager* window.

2. In the *Device Manager*, click and expand the ***Universal Serial Bus controllers*** option to see a list of all USB ports available in the device. To reduce power consumption, the computer may be set to turn off power to USB ports listed as ***Generic USB Hub*** and ***USB Root Hub***.

3. Right-click on one of these USB ports and select ***Properties***. Go to the *Power Management* tab, uncheck ***Allow the computer to turn off this device to save power***, and press ***OK***.

4. Repeat step 3 for **EACH** of the USB ports listed as ***Generic USB Hub*** and ***USB Root Hub***.

5. Close the *Device Manager* once you have finished step 3 for all USB ports.

6. Return to the ***Start*** menu and click *Settings* (gear icon), then select ***Power*** (or *Power & Sleep*) options. For older operating systems, it may be accessed from the ***Control Panel*** under ***System***

and Security. This option can also be accessed by pressing the *Windows key + X* keyboard shortcut and then accessing ***Power Options*** from the pop-up menu.

7. You will see a list of power plans (e.g., Balanced or High performance), and a highlighted radio button will show you the plan currently used by the system. Click on ***Change plan settings*** in front of the currently used power plan.

8. Change the *Put the computer to sleep* option to ***Never***. On some desktops, this may not be an option, which implies it will not turn off or put the computer to sleep. The screen power-saving option will not impact the recording. If you are using a laptop, you will see the options *plugged in* and *on battery*. Change the *plugged-in* setting to ***Never***. In case you don't see this option, you can type it in.

9. Click on ***Change advanced power settings***.

10. Expand the *Sleep* option. Change the *Sleep after* setting to ***Never***. If you are using a laptop, you will see the *Sleep after* setting for ***plugged in*** and ***on batter***y. Change the *plugged-in* sleep after setting to ***Never***. In case you don't see this option, you can type it in.

11. Within the *Sleep* options, if an option exists to ***Allow hybrid sleep***, set it to ***Never***. For laptops, set the *plugged-in* option to ***Never***.

12. Repeat step 11 for the ***Hibernate after*** option under *Sleep*. Remember that you can type in the word ***Never*** in these options.

13. On some older operating systems, the ***USB settings*** option exists (can be searched for in the settings option or the control panel) for the USB selective suspend setting. If so, set it to ***Disabled***. For laptops, disable the ***plugged-in*** options within the USB settings.

14. Go back to the *Start* menu and click on the Settings icon, then find or type in ***Windows Update Settings***. It may also be accessed from the *Control Panel* under ***System and Security*** on some of the older operating systems.

15. Under *Windows Update*, click on ***Change settings*** or ***Advanced options*** (may be at the bottom or in the right panel of the window) and turn off any auto-restart after update settings. Note that if you turn off auto updates, you should periodically manually check for updates on the computer and let it update when an experiment is not running.

Data Acquisition and Monitoring

Starting a Data Acquisition Session

Launch *PiezoSleep* either from the desktop shortcut, from the start menu, or from the location it was saved/installed on the hard drive. The windows shown in Fig. 1 appear after launching the program.

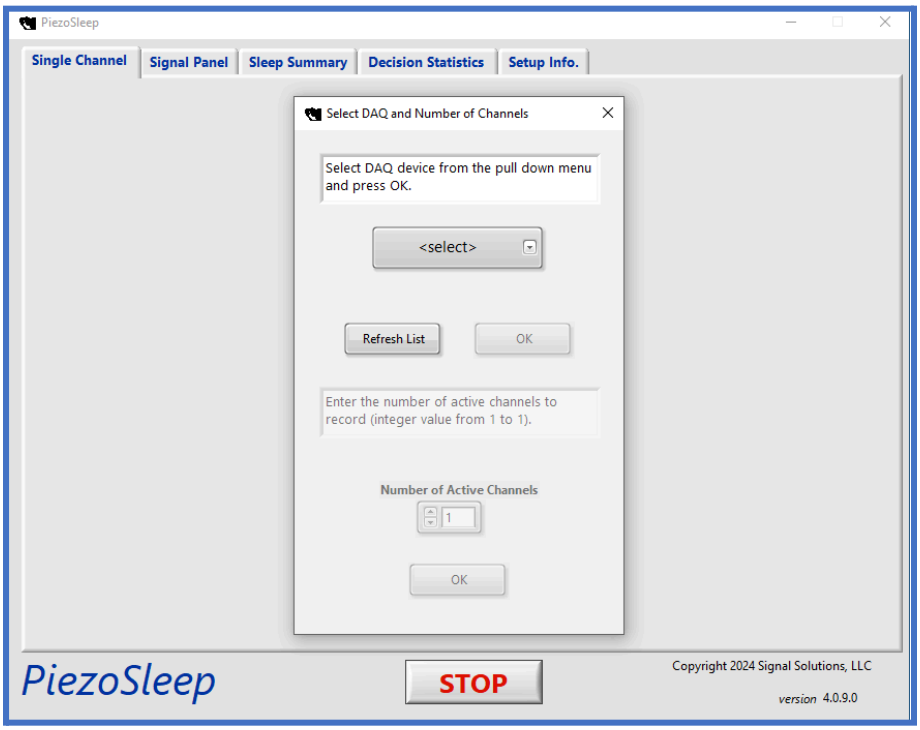


Figure 1: Main user interface (with select DAQ window)

If multiple DAQs are connected to the computer (from other National Instruments systems that are running on the machine), after clicking on select, a drop-down menu will appear listing all the connected DAQs, as shown in Figure 2. In most cases, you will see only one device. If there are multiple devices associated with other data collection activities, then select the one associated with the *PiezoSleep* system. It is typically the newest device plugged into the system. If you are unsure, then temporarily unplug all other National Instrument USB devices to identify

the one associated with PiezoSleep. Make a note of this and select it for this and all future recordings. Once selected, press ***OK*** to move on to the next setting.

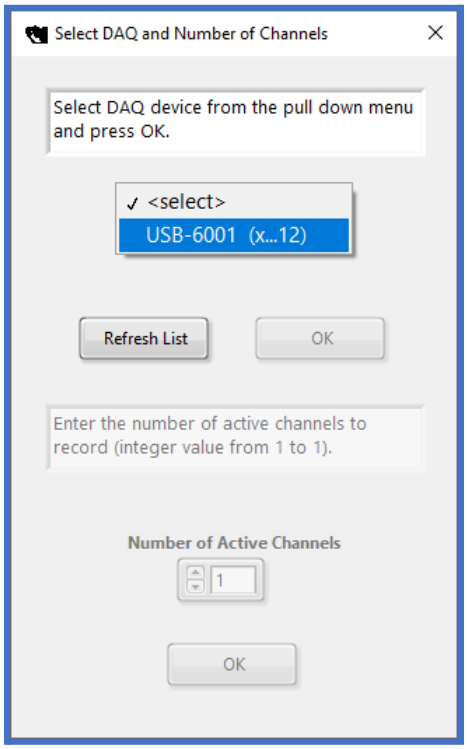


Figure 2: Prompt to select a DAQ.

In the same window, enter the number of active channels in the dialog box shown in Figure 3. This is done so that only the necessary channels will be recorded. The maximum number of channels is based on the DAQ capabilities. If all channels are being used, type in the maximum number. If fewer channels than the maximum will be used, then the number of active channels can be entered to save storage space and result in the later analysis programs running more efficiently. For example, if only 4 animals are to be monitored (cages 1 to 4), then 4 should be entered as the number of active channels. In this case, the cages should be connected sequentially in the acquisition box channels, starting with channel 1 (the first cage is on channel 1, the next on channel 2, etc). If a channel is skipped in the sequence, then enter the number of channels corresponding to the highest channel with a cage for recording attached. For example,

if the cages are plugged into channels 1, 2, 5, and 6, then 6 should be entered for the number of active channels. Channels 3 and 4, in this case, will be recorded, but they will contain only noise and should be marked as empty on the channel labels so they can be ignored in future analyses or used to observe the noise in the recording.

Figure 3: Prompt to enter the number of sequential channels to be recorded.

After you enter the number of active channels, the dialog box in Figure 4 appears. The textboxes can be edited to select a time for light and dark onset, and cage labels. Alternatively, animal ID names can be from an Excel spreadsheet. If you have a spreadsheet file (**.xls* or **.xlsx*) with the animal IDs, the format should be a series of names (text format) under column A, and the number of rows should be equal to the number of active channels selected. If you select ***No***, then you have the option to enter IDs manually for each active channel or use the default channel labels. This information is stored in the file header to be used in subsequent analysis programs like *SleepStats*.

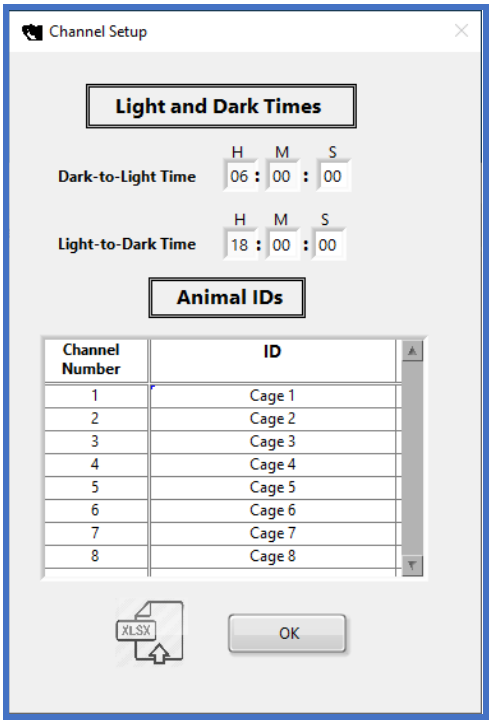


Figure 4: Select Light & Dark times and cage labels, or import a spreadsheet.

The program will then prompt for a file name and location. Animal motion/pressure data will be saved to this file for later processing or checking the signal quality of the recording. It is recommended that this file be given a descriptive name that identifies the nature of the experiment and the date the experiment began. It is also recommended that you do NOT use a period in the file name or type in an extension on the file name textbox, since *PiezoSleep* adds its own extensions, which are used in later programs (the *binfb* extension is given to the files with the unprocessed sensor data that are useful for reprocessing or updating when new algorithms are released). Our software *SleepStats*, which analyzes data after the experiment, uses the base name to look for other files from the experiment and opens them automatically. If they have different names and extensions, the automatic loading will not work, and you will be prompted to search for them with a file/directory navigator.

After selecting the filename and location, the program displays your selections as shown in Figure 5. The display includes the DAQ device, number of active channels, file path, light and

dark onset times, and animal ID names. It also contains a re-selection menu, allowing you to re-select the DAQ device, number of active channels, animal ID names, or filename and location. If no re-selection is needed, then select the last option and click *OK* to continue. Please note that if you re-select the DAQ device, you will also be prompted to re-select the number of active channels and the animal ID names. Similarly, if you re-select the number of active channels, you will also be prompted to re-select the animal ID names. It is recommended that the location of the stored files be noted for later retrieval and archiving.

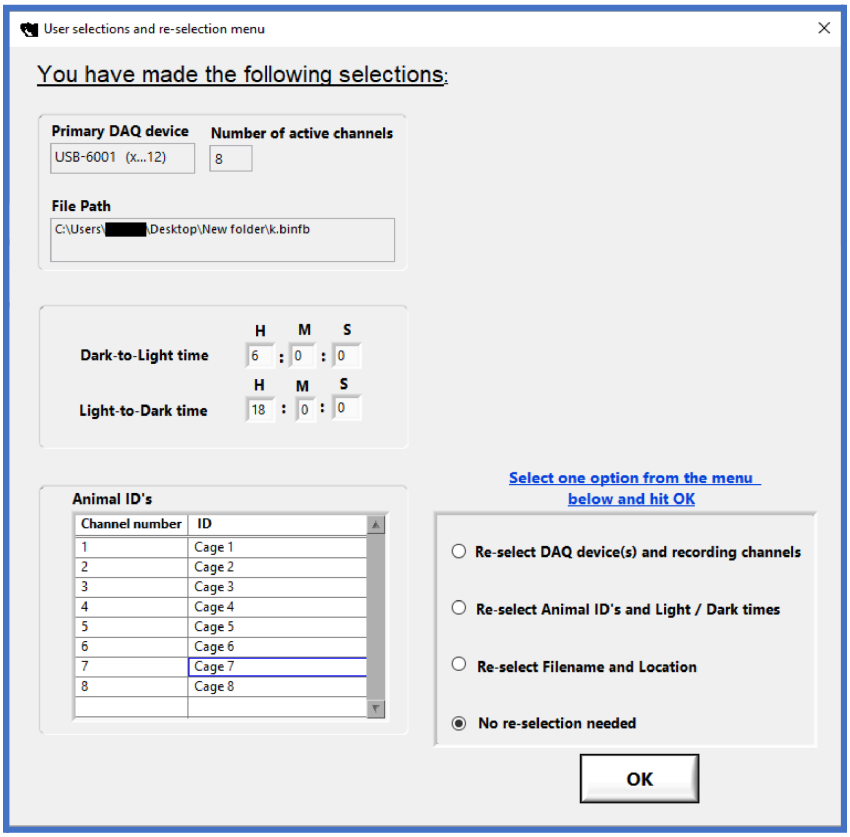


Figure 5: Prompt to check entries made and modify if incorrect information was entered, before the data collection process begins.

The program will now start recording and displaying data. Under each tab, the waveforms/ statistics will begin to appear shortly. When you are finished with your data collection, click the ***STOP*** button located at the bottom of the window.

Ensuring Sensor Connectivity

If you would like *PiezoSleep* to check for disconnected or shorted sensor connections, this option can be enabled through the *Diagnostics* menu. See Fig. 6A below.

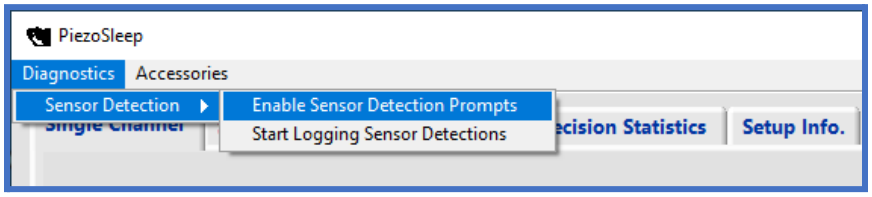


Figure 6A. Diagnostics menu allowing the user to enable sensor detection prompts.

Once enabled, the acquisition system will prompt the user if a sensor short is detected or if a discrepancy is found between the number of channels being recorded vs the number of sensors detected. Three types of prompts can occur.

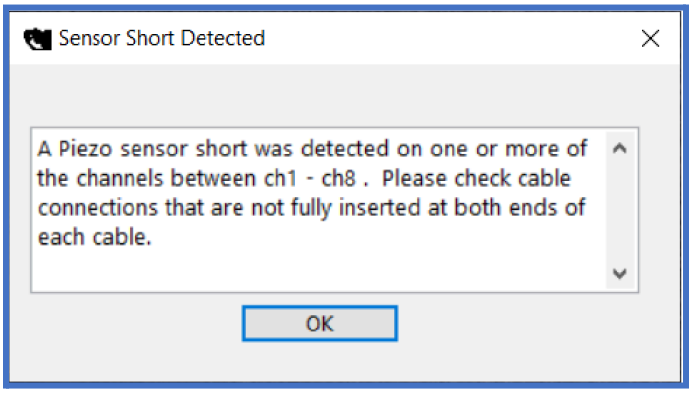


Figure 6B. Prompt alerting the customer if a sensor short is detected. This prompt will continue to pop up until there are no shorts detected.

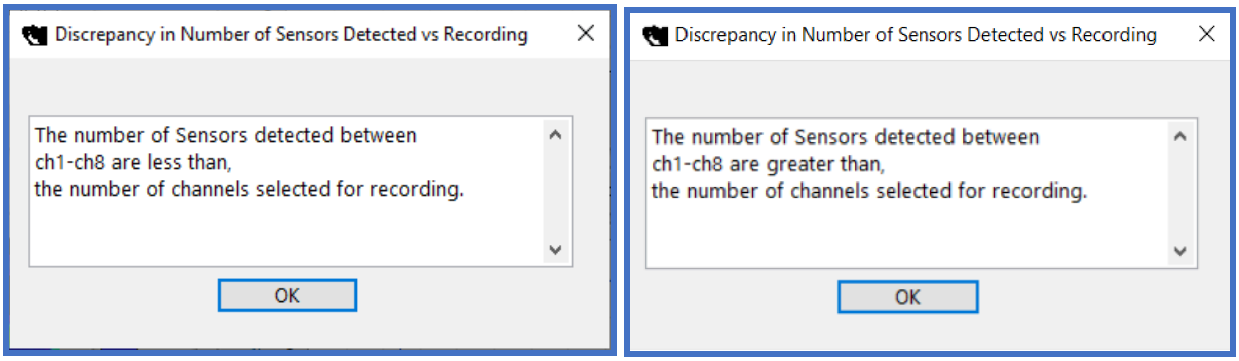


Figure 6(C & D): Prompt alerting the customer if a discrepancy is found between the number of sensors detected and the number of channels being recorded. This discrepancy is only tested when a change in the number of connected sensors is detected.

If any of these messages occur, check the cable connections. You can check the signal panel (described in the ***Monitoring sensor signals for all active channels section***) to look at these channels to see if any have a no-signal (flatline and not responsive to touch) pattern. Then check the cable on both ends to make sure that they are fully plugged in, or water has not come into contact with a sensor. If you can see signals on all the flagged channels, then this could be just a false alarm. If you would like Signal Solutions to confirm whether the sensor detections appear to be false alarms, you can tell *PiezoSleep* to create a sensor detection log file (***.SnsrDet***) and email the file to your contact at Signal Solutions. The ****.SnsrDet*** file will be created and begin logging data once you click ***Start Logging Sensor Detections*** through the *Diagnostics* menu, as shown in Fig. 6E below. The file will continue to be updated, even if prompts have been disabled.

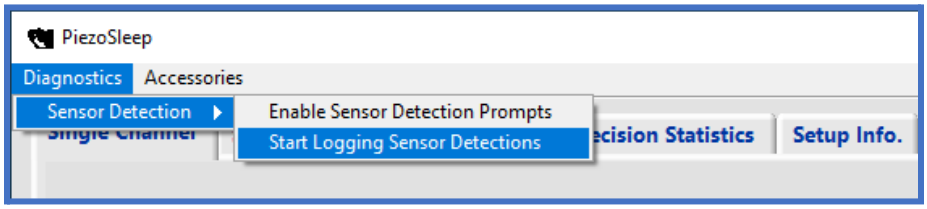


Figure 6E: Diagnostics menu allowing the user to create and begin logging sensor detections to a **.SnsrDet* log file. With this file, Signal Solutions can help determine whether the detection prompts are false alarms.

Note that this feature is turned off by default. For some host computers, the power systems may vary, which can cause excessive false alarms. So, if you enable this feature and you can see an active signal for each cage, and these windows pop up; you can disable this detection feature. To generate an active signal, you can tap on the cage while looking at the display panel, or if a live animal is in the cage, you should see signal variations associated with the cage.

Selecting and monitoring a channel signal (Single Channel tab)

The *Single Channel* tab displays the most recent 8 seconds of the recorded signal along with additional graphical descriptions. As shown in Fig. 7a, the tab consists of four panels, displaying the pressure signal (top left), sleep decision statistic (top right), power spectrum/spectrogram (bottom left), and the breath rate frequency (bottom right) for a given channel. By default, the spectrogram is showing, but you can toggle between this and the spectrum. To view a particular channel, you can type the channel number into the ***Channel to Analyze*** text box or use the up and down arrows to the right of the text box.

To facilitate real-time observation, the *PiezoSleep* program computes and updates the power spectrum, breath rate, and the sleep decision statistics every 2 seconds. The power spectrum shows the signal's power distribution over a range of frequencies. The amplitude on the y-axis is expressed in the logarithmic unit decibels (dB). The sleep decision statistic comprises a histogram plot showing the sleep-wake distribution for the selected channel. Detection is based on comparing the real-time decision statistic to a sleep threshold, which by default is zero and is depicted on the histogram by a blue vertical line. Larger positive decision statistics indicate a greater likelihood of sleep, while negative decision statistics indicate a greater likelihood of wake.

NOTE: The real-time, statistics, and classification are about 5 to 10% less accurate than the decision analysis program *SleepStats*, which performs a more extensive calibration than is possible in real-time. This is done for recording 24 hours or more. Therefore, all assignments of

mouse sleep behavior should be made using *SleepStats* after the recording is complete. The purpose of the real-time monitoring is to check on potential outlying behavior, sick mice, or bad connections while the experiment is running so that potential corrections can be made.

The breath rate plot displays the most recent 32 minutes of data, updating itself once every 2 seconds. For the first 32 minutes after starting the program, the breath rate plot will accumulate data and, from then on, plot the most recent 32 minutes of data. If the signal is too irregular to estimate an average breath rate, then a zero is output to the plot.

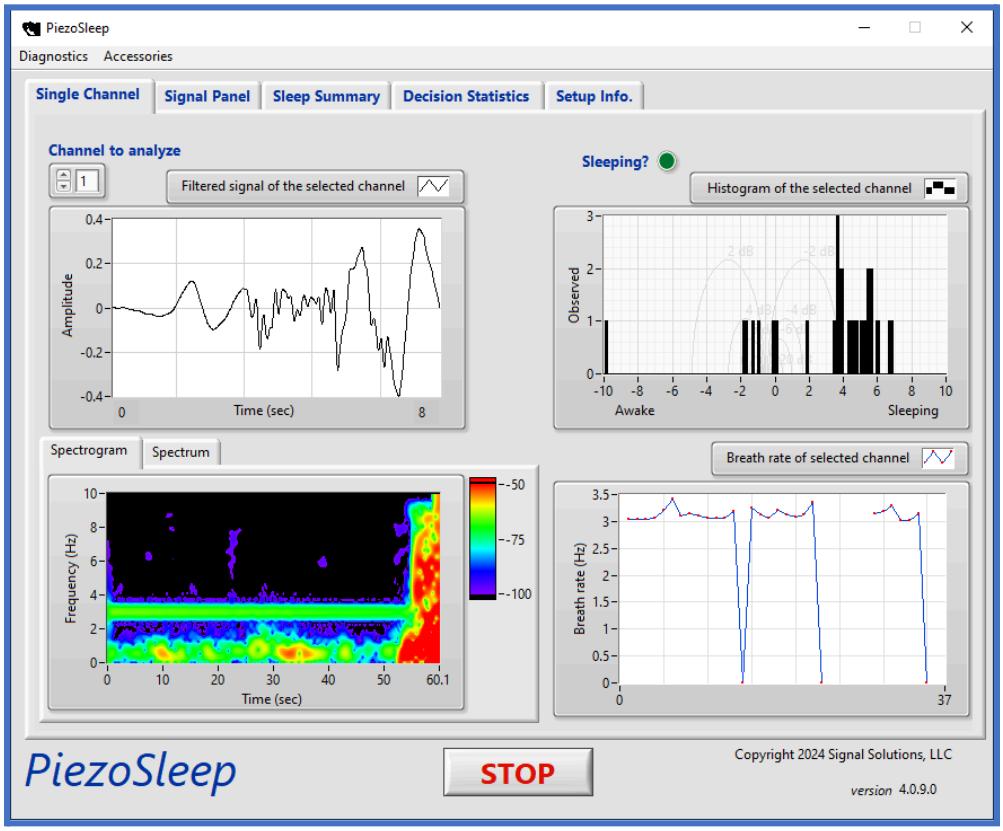


Figure 7a: Single Channel tab

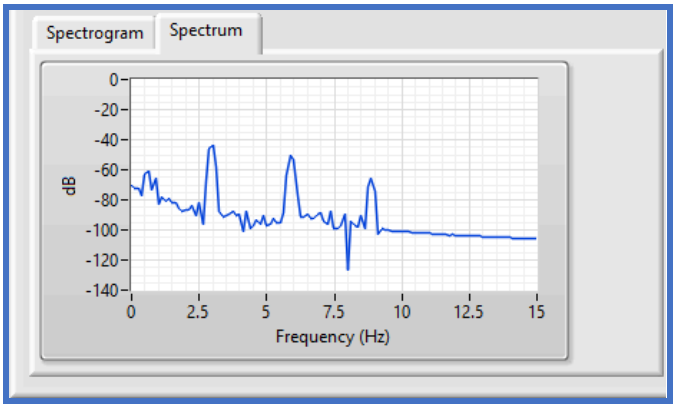


Figure 7b: Spectrum tab

Monitoring sensor signals for all active channels (Signal Panel tab)

To simultaneously view sensor signals for the active channels, click the *Signal Panel* tab. This panel, shown in Fig. 8, displays 4 active channel signals over the last 8 seconds. If there are more than 4 active channels, use the ***Page*** text box to page through the rest of the channels. The animal IDs with their corresponding channel number are displayed over each plot.

The thin green bar (virtual LED) above each plot on the Signal *Panel* is the sleep indicator. A lit indicator implies detected sleep, as seen for channel 1 in the figure. The y-axes of the graphs on the *Signal Panel* are fixed from -0.4 to 0.4 volts (volts are proportional to pressure). These graphs, by default, do not auto-scale the signal like the filtered signal plot on the *Single Channel* panel, so relative amplitudes can be observed. The primary purpose of these graphs is to view signals from all cages quickly to see if there are problems (broken connections, amplifiers not plugged in, dead mice, etc.). However, by right-clicking on the y-axis of these graphs, you can turn on the auto-scale to see more detail for weaker signals. To go to a fixed scale, set to manual scale, and directly click on the y-axis numbers (maximum and minimum) and type over to set the limits. There is a 2 to 4-second delay between what is happening in the cage and what appears on the screen.

Figure 8: Signal panel

Monitoring percent sleep for all active channels (Sleep Summary tab)

The percentage of sleep for each channel can be observed at any point during the recording in the *Sleep Summary* panel shown in Figure 9. The percentage is based on the sleep threshold and the histogram formed from the accumulating data. Outliers can be identified here early in the experiment and can be followed up with direct observation of the animal or checking the function of the sensor (e.g., ensuring the cable is plugged in). Again, *SleepStats* will provide more accurate numbers after the experiment has been completed.

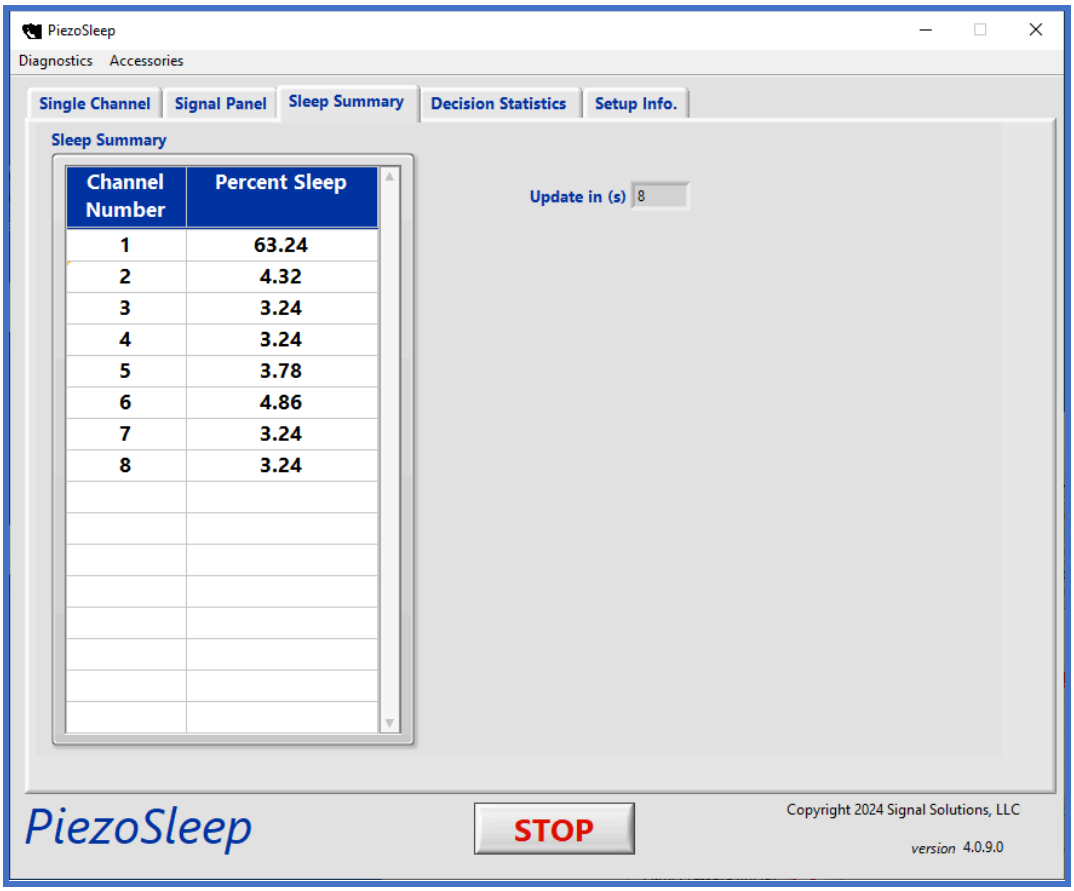


Figure 9: Sleep Summary

Monitoring decision statistics for all active channels (Decision Statistics tab)

To simultaneously view the sleep-wake decision statistics for the active channels, click the *Decision Statistics* tab, which shows histograms for 4 active channels at a time, as illustrated in Figure 10. The animal IDs with their corresponding channel number are displayed over each plot. If there are more than 4 active channels, use the ***Page*** text box to view results from the rest of the channels. This provides a quick way to examine the data collection and sleep-wake behavior over the experiment. Unusual behaviors or data collection problems can be identified while the experiment is running, which can be addressed by direct observation of the animal. For example, after running the program for 24 hours with a normal/control animal, a bimodal distribution should appear in the histograms from mapping sleep signal dynamics toward

positive values and wake signal dynamics toward negative values. If the histogram is not bimodal, it could be the result of noise or weak signals, for which there are several causes:

- An electrically or mechanically noisy environment
- Poor animal contact with the piezoelectric sensor on the floor of the cage (sometimes caused by too much bedding or the cage shield not being properly seated on the sensor platform)
- Faulty amplifier or sensor
- Unusual animal behavior not observed in the training phase of the classifier (i.e., animal is ill, dead, or has a very unusual respiratory pattern during sleep)

The bimodal pattern in the histogram is exploited by adaptive thresholding, used in later analysis programs, which seeks a minimum point between the clusters (modes) of decision statistics. Real-time analysis is limited in that it uses the same threshold over all channels and can vary by as much as 10% from the later analysis using an adaptive threshold. The primary purpose of real-time monitoring in the acquisition program is to alert those monitoring the experiment. If problems arise, they can be verified (by direct observation of the animal) or corrected during the experiment. More accurate sleep and wake parameters are generated with the *SleepStats* program. More than one panel (group of 4) can be examined simultaneously by undocking the current tab using the arrow in the upper right of the plot panel.

Figure 10: Decision Statistics

Current file and setup information display (Setup Info tab)

After data collection has begun, current information and settings will be displayed on the *Setup Info* tab, as shown in Figure 11. The display includes: Start Time, Number of active channels, Primary and Secondary DAQ selections and their channel information, pseudo LED showing Auxiliary DAQ usage, File Path, and Light and Dark transition times. These selections were made by the user at the start of the data acquisition session. The start time is stored in the data file header, so it is saved with the data to create an absolute time axis for computing statistics related to the light and dark periods, as well as confirming the date the experiment began.

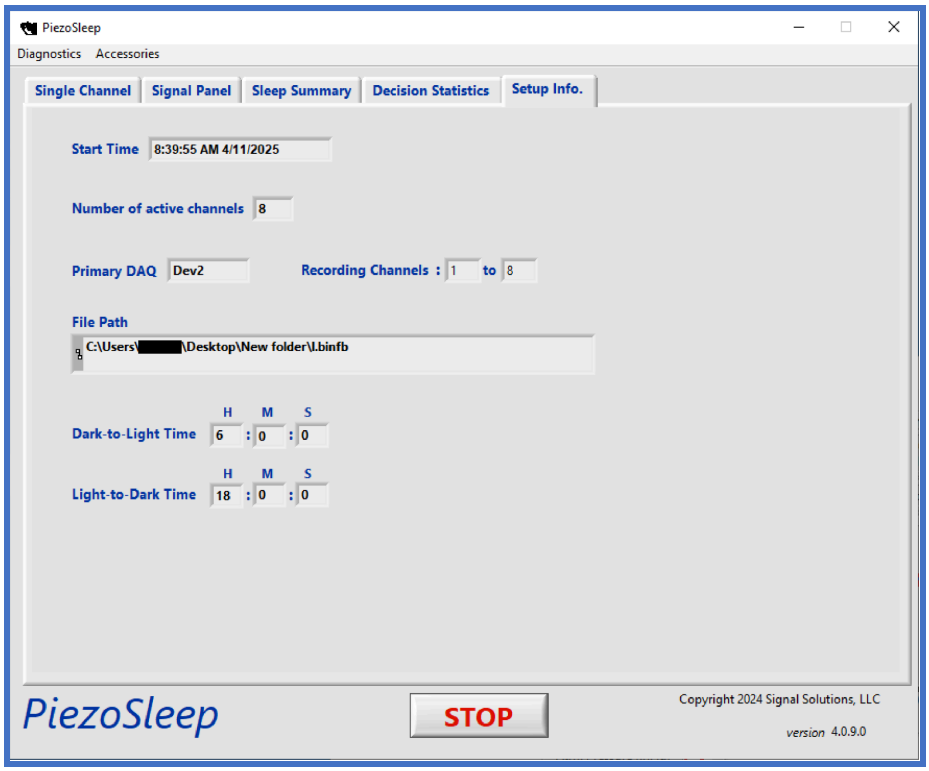


Figure 11: Setup Info

Logging Environmental Sensor Data

If an environmental sensor accessory is attached via USB, the user can begin logging and/or viewing this data through the ***Accessories*** menu as shown in Figure 12 below. If logging has already been started, then clicking the ***Environmental Sensor*** in the menu will show the Datalogger data window shown in Figure 14.

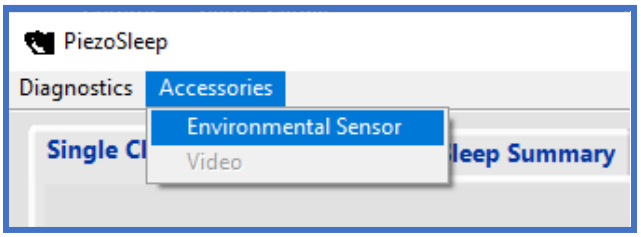


Figure 12: Accessories menu showing access to Environmental Sensor

If environmental sensor data is not currently being logged, then clicking *Environmental Sensor* in the *Accessories* menu will open the settings window shown in Figure 13 below. If there are no sensors shown and you have the device connected to the USB, click the ***Rescan Devices*** button. Once the device is shown, the device label can be modified to tailor it to the experiment. Under the ***Other Settings*** menu, there is an option to ***Disable LED***. The LED being referred to here is a physical LED on the sensor that blinks each time the device is sampled. Disabling the LED will prevent it from illuminating. Once the settings are complete, clicking the ***Begin Logging*** button will open the Datalogger window, which graphs the acquired data.

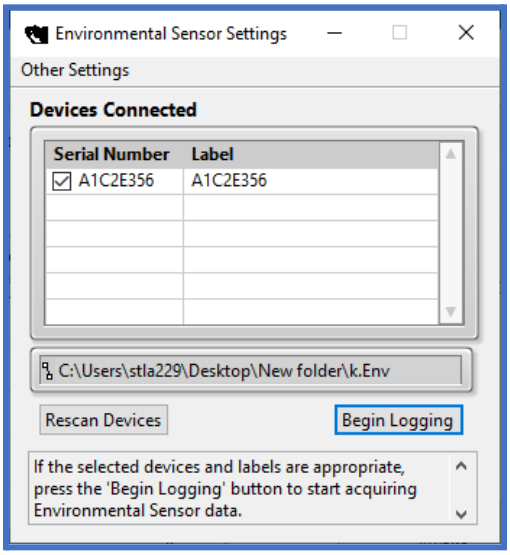


Figure 13: Environmental Sensor Settings Window

After clicking the ***Begin Logging*** button in the settings window, environmental sensor data acquisition begins. The data is stored in a binary file with ****.Env*** extension in the same directory as the **.binfb* file. As previously mentioned, once logging has started, the Datalogger window in Fig. 14 can be accessed through the ***Accessories*** menu in Figure 12. The Datalogger window can be minimized or closed, and acquisition will continue to run in the background. At the end of the experiment, when the main *PiezoSleep* window is closed, the environmental sensor acquisition will be stopped automatically.

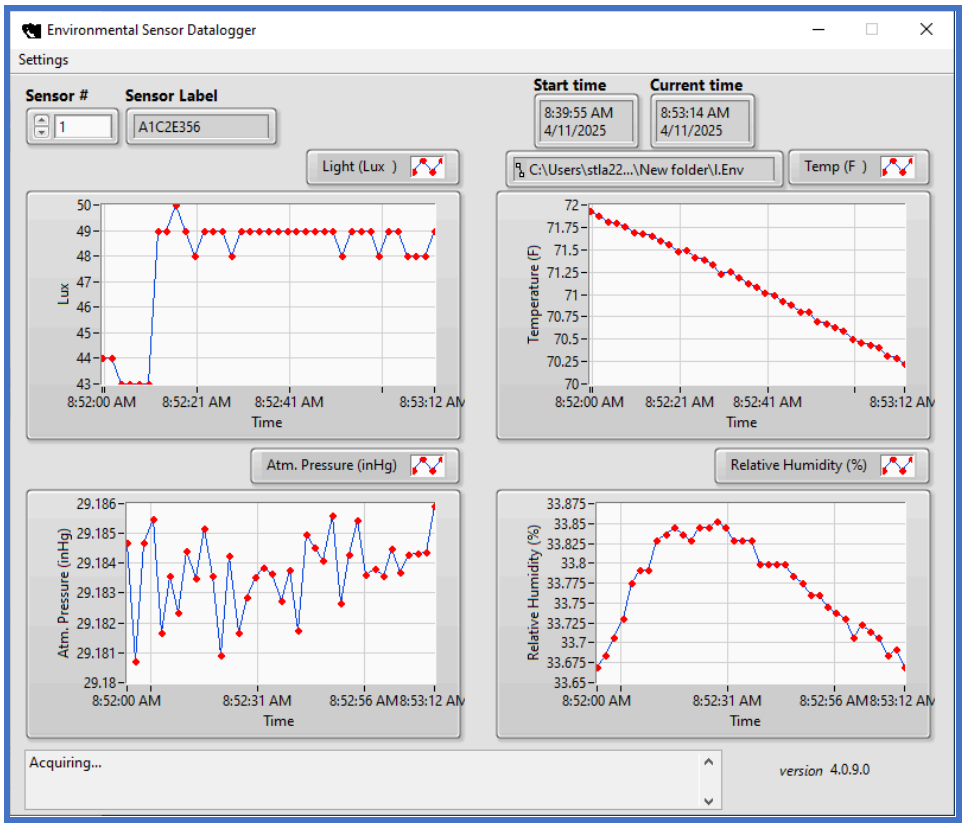


Figure 14: Environmental Sensor Datablogger Menu

If logging has already been started and you would like to add another sensor, you may add it by accessing the ***Settings*** window from the Datalogger menu.

Synchronized Video Acquisition

The video recording module can be accessed from the ***Accessories*** menu as shown in Figure 15, or by selecting ***Yes*** on the "*Would you like to record video?*" prompt during startup, shown in Figure 16.

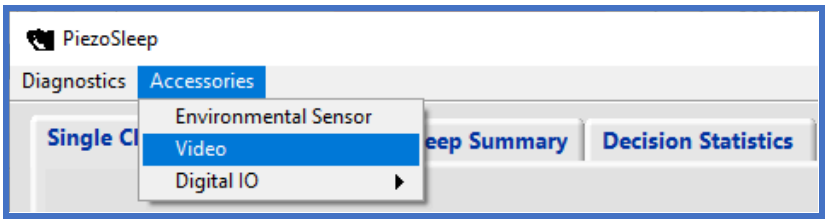


Figure 15: Accessories menu showing access to Video Acquisition

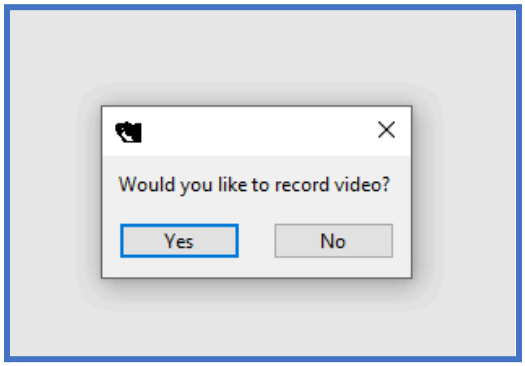


Figure 16: Option to record video during startup

Video Module Startup

When launched, the video module scans the network for adopted cameras and populates the ***Camera Assignment*** table with supported devices, as shown in Figure 17. Once initialization has completed, the message pane (located at the bottom of the *Camera Settings* window) will report *Done*.

NOTE: The video module initialization process may take several minutes.

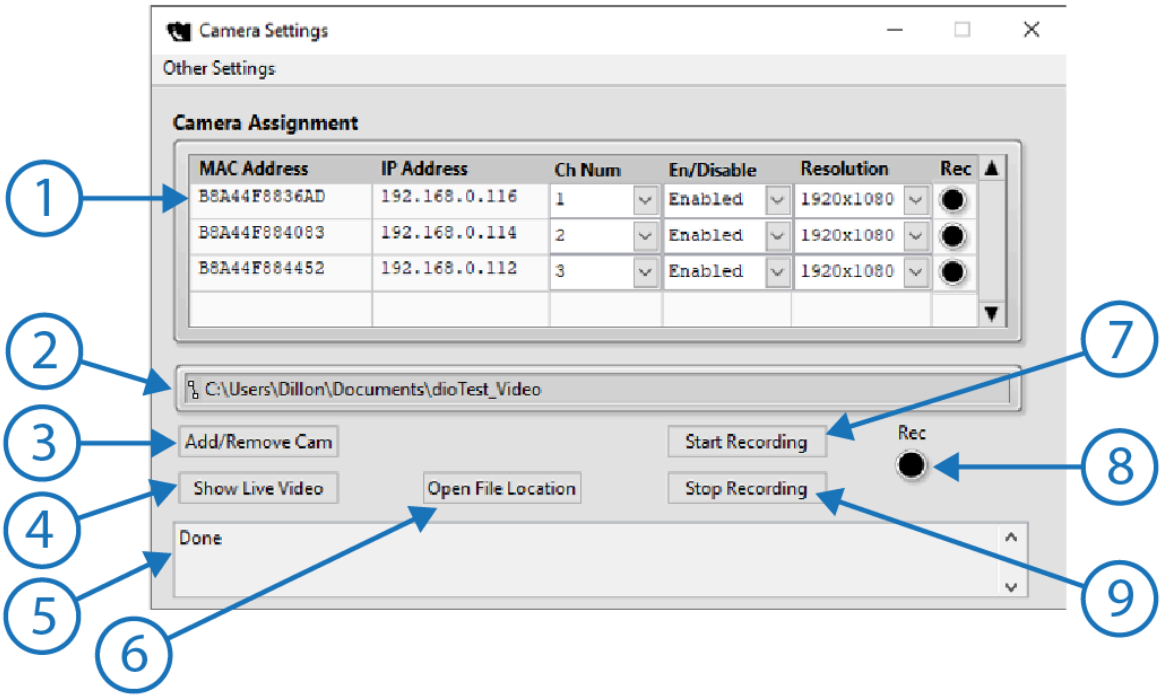


Figure 17: Camera Settings window

1 - Camera Assignment Table

Table control to assign the camera to the piezo channels, enable/disable for recording, and set the video resolution

2 - Video Recording Save Directory

Indicates video data directory. The video folder will be located in the piezo data save directory in a folder ending with "_video". Each camera will be stored in individual subdirectories (CAM_1, CAM_2, etc) with the number indicating the assigned piezo data channel.

3 - Add/Remove Cam

Launches the Camera Adoption tool

4 - Show Live Video

Launches the video live feed window

5 - **Message Pane**

Indicates current module status

6 - **Open File Location**

Opens the video folder directory in File Explorer

7 - **Start Recording**

Initiates recording for all enabled cameras

8 - **Recording Indicator**

Blinks red if any camera is actively recording

9 - **Stop Recording**

Stops all actively recording video streams

Camera Adoption Process

The camera adoption tool can be accessed by clicking the ***Add/Remove Cam*** button on the *Camera Settings* window. When launched, the software will scan the network for supported cameras and return a list of MAC addresses and IP addresses associated with supported devices.

To adopt a camera, select the camera(s) in the ***Cameras Not Adopted*** list (multiple devices can be selected at a time by holding CTRL while clicking), and click the ➡ button to move the camera(s) to the ***Adopted Cameras*** list. Likewise, you can use the ⬅ button to remove a camera from the adopted camera list.

Once all cameras have been adopted, click ***Done*** to save the configuration.

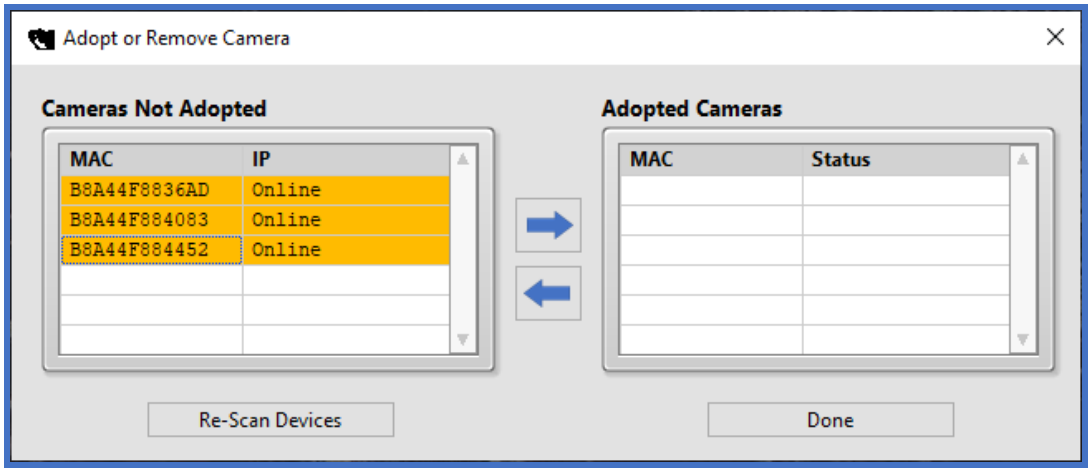


Figure 18a: Adopt or Remove Camera window (cameras selected)

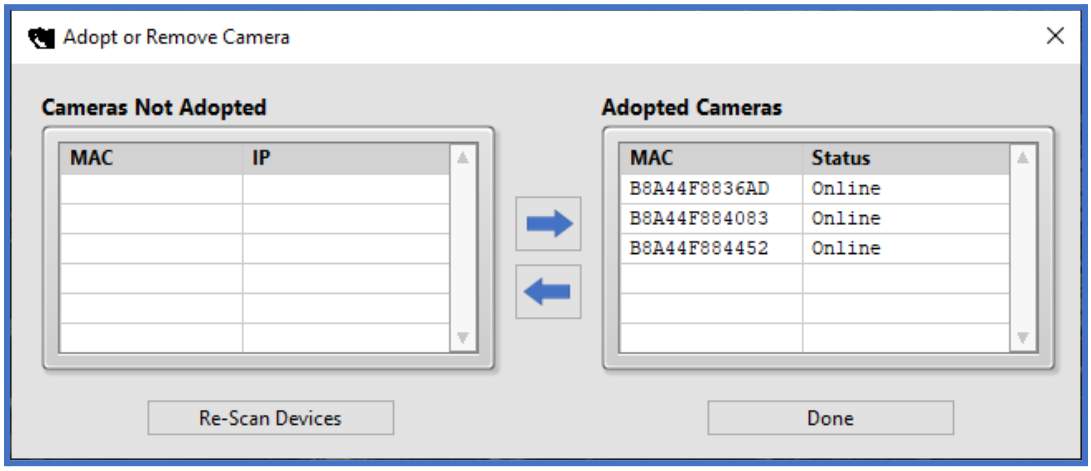


Figure 18b: Adopt or Remove Camera window (cameras moved to *Adopted Cameras* List)

NOTE: Adopted cameras will then be displayed in the ***Camera Assignment*** table of the C*amera Settings* window, as shown in Figure 19. By default, the cameras will initialize with no channel assignment (*n/a*) and disabled.

Cameras will need to be assigned to Piezo recording channels before they can be enabled for recording.

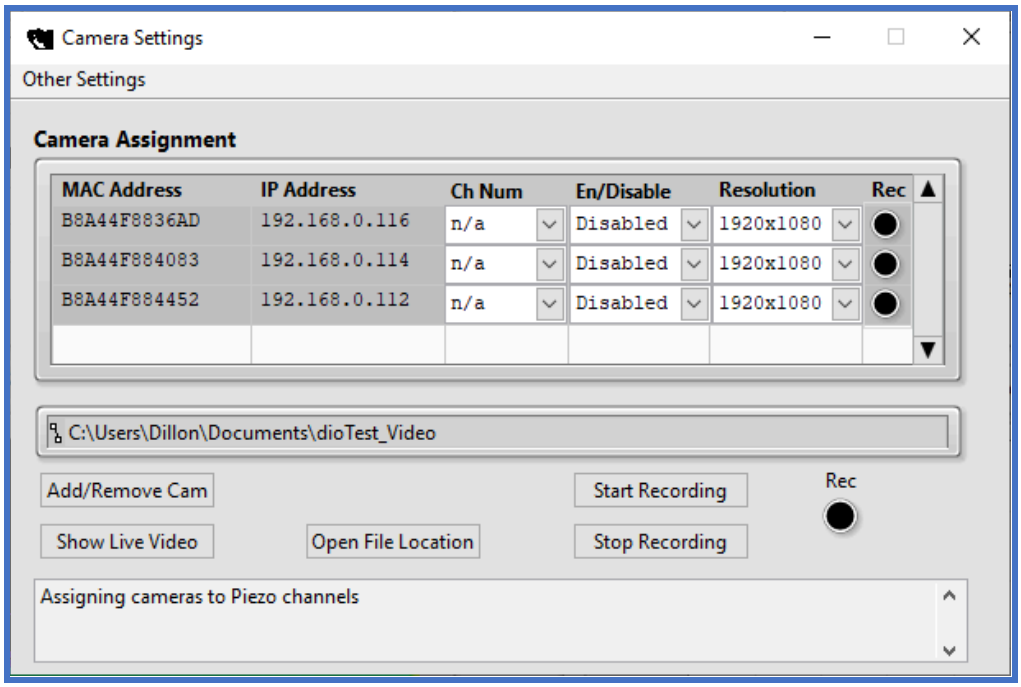


Figure 19: Camera Settings window with adopted cameras

Assigning Cameras to Piezo Channels

Open the video live stream by clicking the ***Show Live Video*** button on the *Camera Settings* window. For each video feed, identify the appropriate *Channel Number (**Ch Num**)* from the video feed, and update the corresponding entry in the *Camera Assignment* according to the camera MAC Address (the MAC address is listed in the bottom right corner of the video feed). Clicking a row of the *Camera Assignment* table will update *Live Stream* to the selected camera's video feed.

NOTE: Only a single camera can be assigned to a given data channel.

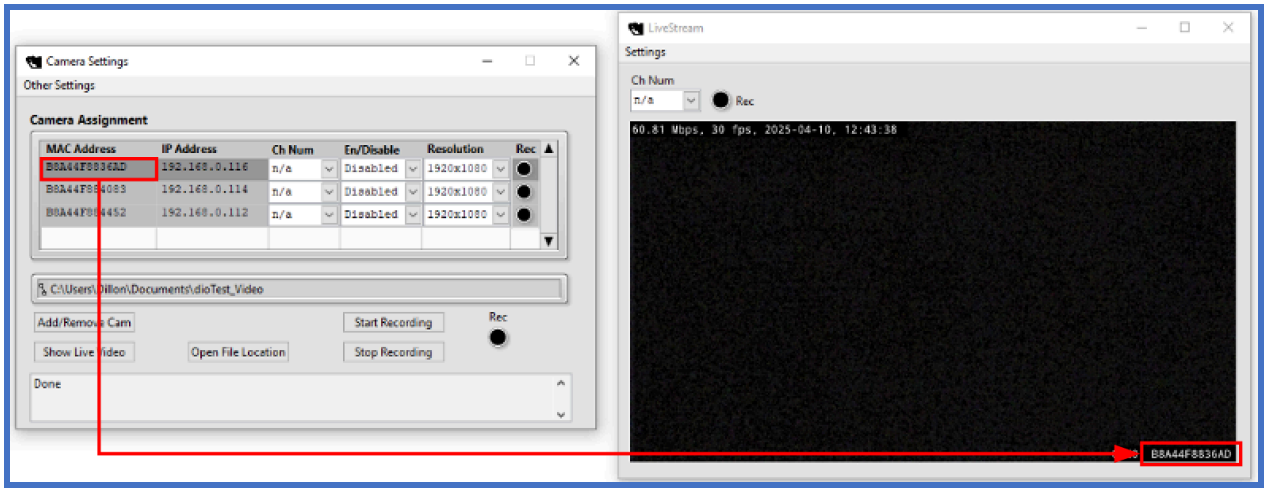


Figure 20a: Camera Setting window with Live video (MAC Address in bottom right corner)

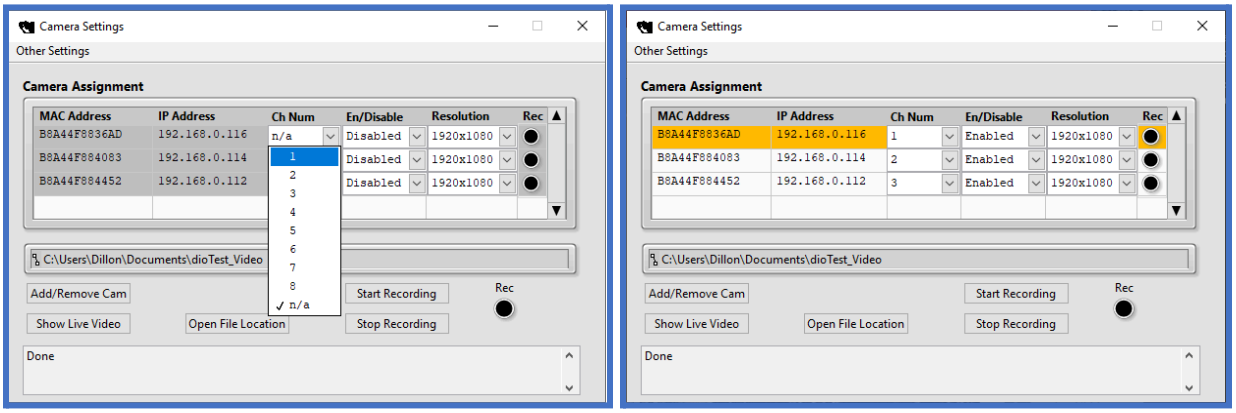


Figure 20b & 20c: Assigning channel numbers to cameras (b) and selecting a channel to view live (c)

Digital I/O

Digital I/O allows for hardware-level interfacing with third-party devices. When a digital signal is registered on a Digital Input channel, the event is logged to a file by PiezoSleep. The software can also generate digital outputs, either in closed-loop (i.e., upon detection of sleep) or open-loop (i.e., on a time interval).

If the data acquisition unit is equipped with a Digital I/O accessory, the *Digital I/O* menu will be populated in the Accessories menu.

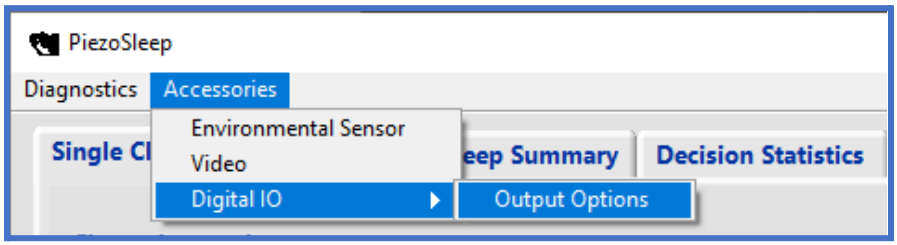


Figure 21: Accessories menu showing access to Digital I/O

Digital Output Control Interface

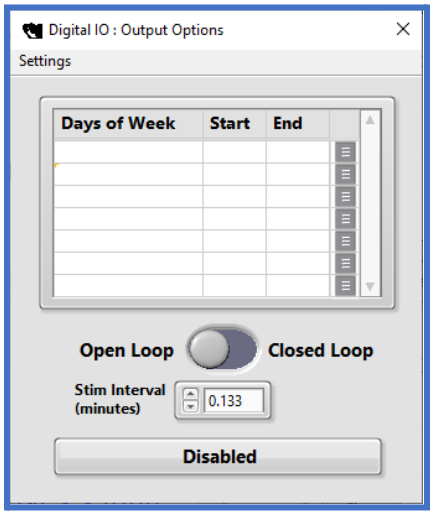


Figure 22: Digital Output Interface

The Digital IO: Output Options window allows for configuring the digital output configuration. Digital output can be triggered in either ***Closed Loop*** (i.e., triggered upon the detection of sleep) or ***Open Loop*** (i.e., triggered at a fixed time interval).

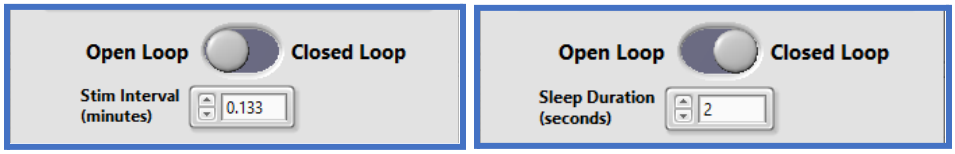


Figure 23a & b: Digital Output Interface Open/Closed Loop

When selecting **Open Loop**, all digital output channels will be triggered according to the specified *Stim Interval*. In **Closed Loop**, the output will be triggered when a channel has been detected to be in sleep for the specified amount of time.

Defining Output Time Periods

The digital output will be triggered according to the selected protocol during time periods defined in the module.

A new time period can be defined by clicking the icon in the time period table. Once clicked, a window will appear to specify the time and day of the week.

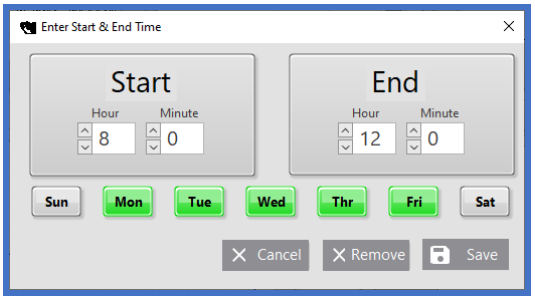


Figure 24: Enter Start & End Time window

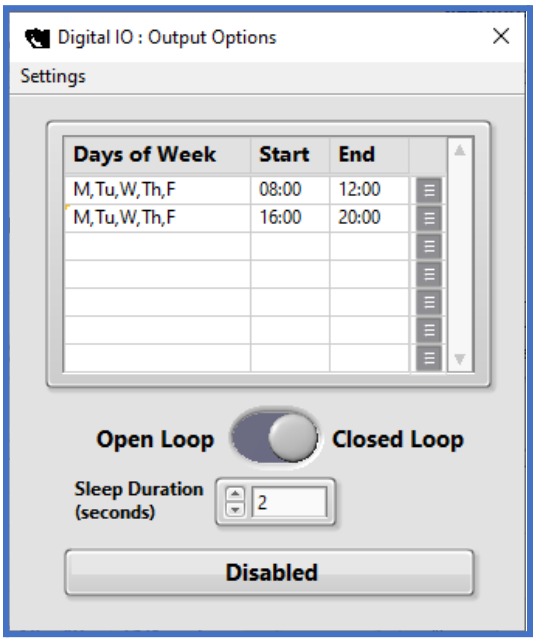


Figure 25: Digital Output Interface with time periods

File Information

PiezoSleep saves four piezo data files by default. The file with a base name (provided at the beginning of the data acquisition session) and the ***bin/binfb*** extension stores the raw data from the piezo sensors. The file with the ***Feat/Featfb*** extension and ***_br*** padded to the base name stores the breath rates for all channels. The *Feat/Featfb* file with ***_at*** padded to the end stores a measure of general activity for all channels. The file with the ***FeatVec/FeatVecfb*** extension stores the feature vectors used to calculate the sleep statistics. These files are used by the analysis program *SleepStats*, developed by Signal Solutions, LLC. Files are updated to the disk at least once every 2 seconds during the data acquisition session. Therefore, if the system crashes due to a power failure, data up to the point when the computer system failed is saved.

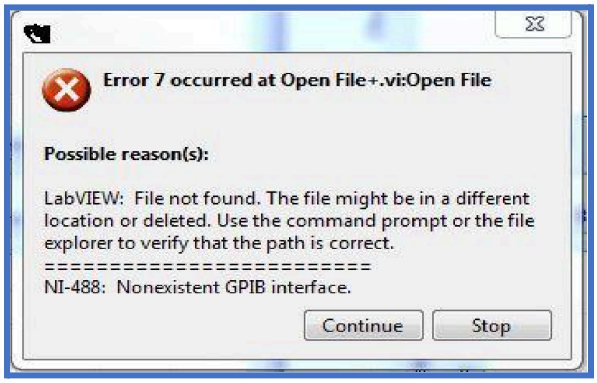
The program samples the piezoelectric signals at 120 Hz and 16 bits (2 bytes) per sample per channel. A 16-channel recording will write 332 MB of data per day. If disk storage is limited, it may be necessary to stop data collection periodically, remove existing data files, and restart the recording with a new file. This, however, complicates file and data management. It is best to have a computer with enough hard disk space and removable media to transport the large files to other systems for archiving and analysis. The size of the raw piezo data file can be estimated in terms of the number of days and active channels by the following formula:

$$B = \frac{(2*24*602*120)*d*c}{10^6} \approx 20.74 \text{ dC}$$

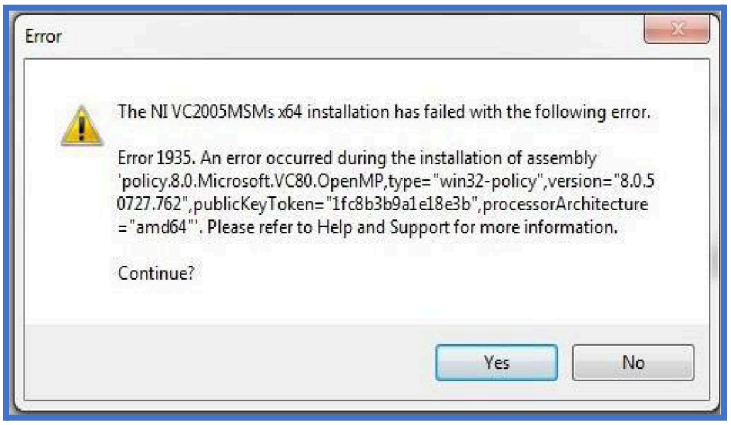
D is the number of days, C is the number of active channels, and B is the file size in megabytes (MB). The *Featfb* and *FeatVecfb* files are considerably smaller in size compared to the piezo binfb file. The *Featfb* file consumes space at about 0.34 MB/day, and the *FeatVecfb* file consumes roughly 1.4 MB/day for each channel as compared to the 20.74 MB/day for the *binfb* file.

Troubleshooting

Troubleshooting errors during PiezoSleep installation or operation



This error generally occurs when the software is being run from a user account different than the one it was installed using. Please switch to the user account used during the installation of the ***PiezoSleep*** software and try running the software again.



This error generally occurs due to the following two reasons:

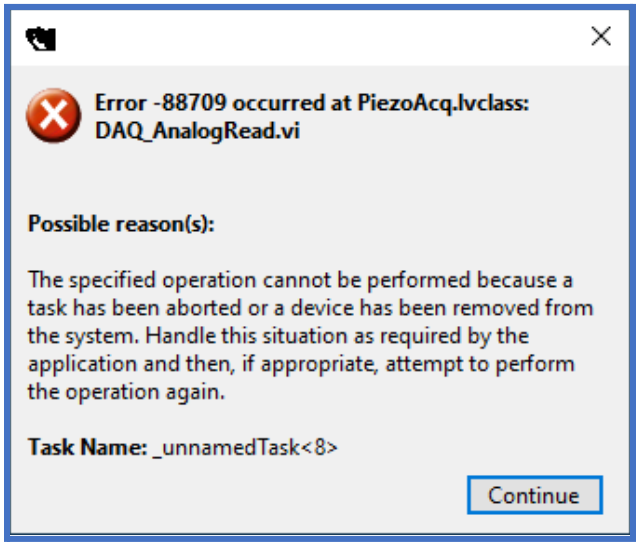
1) Windows Update is running or has some updates pending.

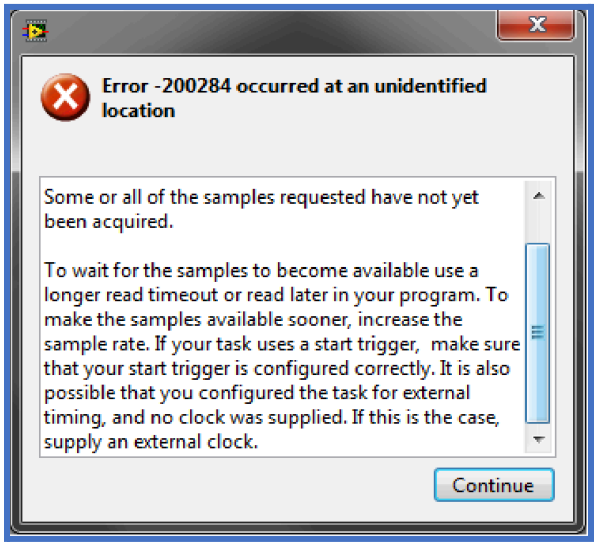
2) The anti-virus software in your system is blocking the installation of “NI VC2005MSMs” because it sees it as a threat.

Please do the following:

1) Turn off the anti-virus software and firewall temporarily.

2) Go to the system's 'Control Panel' and check if there is any 'Windows Update' running or pending. If that's the case, finish updating and then restart your system and try the installation again.





These errors generally occur when the USB port on your computer, which powers the DAQ, loses power (i.e., shuts down). Please refer to the section on ***Computer Settings*** of the manual and make the appropriate changes.